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IN THE CRATER OF HALEMAUMAU, HAWAII, JANUARY, 1915.—[See page 214.]

Some Recent Discoveries in Astronomy*

Various Directions in Which Important Progress Has Been Made

The sun, after an unusually long period of inactivity, has at last shown signs of life. Since April, 1914, large groups of spots and bright faculæ have appeared in high solar latitudes, a position which indicates that they belong to a new solar cycle, for spots belonging to the preceding cycle would have appeared in the equatorial region.

A very fine spot was observed near the center of the solar disk on August 21st, 1914, the date of the total solar eclipse which was one of the most important astronomical events of the past year. The zone of totality traversed Norway, Sweden and Russia, from the Arctic Ocean to the Black Sea, and the duration of totality—about two minutes—attracted many specialists from Europe and America. The outbreak of the war, however, forced some expeditions to turn back, prevented others from receiving their instruments, and compelled still others to establish themselves in Sweden or Norway, instead of Russia.

I started from Paris, with my assistants, on July 19th, so that we crossed Germany without difficulty and arrived at Theodosia, Crimea, a few days before war was declared. My assistants, however, were soon recalled to join the army. Left alone, I was forced to limit my programme to photographing the eclipse with a lens of 40-feet focus, which I had used for the same purpose in 1905. A few days before the eclipse, the arrival of our colleague, Mme. Chandon, brought me valuable aid.

On my plates, the corona presents the appearance that would be expected in the actual phase of solar activity. It is not exactly the corona of minimum activity, for the polar rays are quite long. It indicates, rather, that the minimum had been passed about a year previously, a date which agrees better with the normal cycle than the date indicated by the belated appearance of the sunspots.

Between the polar rays, dark spaces extend almost to the sun's limb. These voids are not easily explained, if the corona is not confined to the plane of projection, but completely surrounds the sun.

I was unable to observe the spectrum of the corona, but other observers noted a bright red line which had not appeared, with equal brightness, in preceding eclipses. MM. Bosler and Block, of the expedition from the Meudon Observatory, give 637.45 as the wave length of this line. On the other hand, the green line of the corona and other characteristic lines in the blue were absent or very weak. It appears, therefore, that the intensity of the corona lines varies from eclipse to eclipse, and this fact indicates corresponding variations in the proportions of the gaseous constituents of the corona.

Within the past year, the ninth satellite of Jupiter was discovered, in a photographic search conducted by Nicholson, at the Lick Observatory, in California. The satellite, which on the plates appears like a star of the 19th magnitude, accomplishes its revolution in 3 years. It is the most distant of the satellites, and like the eighth, has a retrograde motion.

The comet discovered late in 1913 by Delavan, who announced that it would pass its perihelion 10 months later, became visible to the naked eye in August, 1914, and developed a tail 5 degrees long before it reached its perihelion at the end of September. Its perihelion distance was 1½ times the earth's distance from the sun. Photographs of this comet, made by Quérisset, have been reproduced in our *Bulletin*, but no work on its spectrum has been published, to my knowledge.

Smaller comets have been discovered by Kritzinger, Zlatinsky, Neujmin and Lunt.

The return of Encke's comet was particularly interesting, because it appeared as a star of the 6th magnitude, although it had previously shown diminished brightness at each reappearance. According to Crommelin, this unusual brilliancy was due simply to the relative positions of the comet, the earth and the sun, and it should be manifested whenever the comet passes its perihelion in December.

Numerous observers have discovered and measured double stars, hitherto unknown.

Several American observatories have undertaken the measurement of stellar parallaxes, and the American Astronomical Society has appointed a committee to coordinate the results, including those obtained by a few European observatories.

At Mount Wilson, measurements of the radial velocities of stars of known parallax, and of magnitudes higher than 5.5, are being made. General progress has been made in the study of the distribution and movements of the stars.

Stellar spectroscopy has, likewise, progressed. In particular, the interferential methods of Pérot, Fabry and Buisson promise to be fruitful of new discoveries. Diffraction gratings give greater dispersion than can be obtained with prisms, but the interferential methods, which were first employed by Michelson, give still greater dispersion, with little diminution in brightness. The apparatus of Pérot and Fabry comprises two plane-parallel glass plates, exactly parallel to each other, with their opposing faces lightly silvered. A pencil of light that traverses both plates directly interferes with one reflected repeatedly by the silvered faces, producing a series of concentric rings, alternately bright and dark, of diameters depending on the wave length of the light.

Several years ago Pérot applied this very exact method of measuring wave lengths to the determination of the rotational velocity of the sun at different latitudes. More recently, Fabry and Buisson, have employed the same method in a spectroscopic study of the Great Nebula of Orion which, like other gaseous nebulæ, emits a limited number of monochromatic radiations and is consequently a very suitable object for this method. The parallel glass plates were mounted just outside the eye-piece of the refractor of the Marseilles Observatory, the mirror of which, made by Foucault, has a diameter of 32 inches and a focal length of 173 inches. The eye, looking through this optical system, sees a series of dark rings, superposed on the image of the nebula. These rings correspond to the bright green line of wave length 500.7, which dominates the other radiations, but a photographic plate, substituted for the eye, shows rings corresponding to the hydrogen line H_γ, of wave length 434.1, and to the line of wave length 372.7 which has been assigned to the hypothetical element nebulium.

Some very interesting results obtained by this method have been published within the past year. The radial velocity of the nebula can be deduced from comparative measurements of the diameters of the hydrogen rings of the nebula and the diameters of the rings produced by a Geissler tube filled with hydrogen. The measurements of the photographic plates indicate that the Orion nebula is moving away from the sun with a velocity of 15 kilometers per second. Velocities ranging from 16 to 18 kilometers have been obtained by Keeler, Wright, Frost and Adams, with prism spectroscopes.

The interferential method, however, is so precise that it detects differences of velocity at different points and furnishes evidence that the nebula is rotating, with a surface velocity of 5 kilometers per second.

When the radial velocities of all parts of the nebula are known, the measured wave lengths of radiations of unknown origin can be reduced to the values which they would have if they emanated from a source at rest, relatively to the earth. This has been done for the nebulium line, which is double, as Wright first discovered. Fabry and Buisson have determined the wave length of each component to 1/100 angstrom, i. e., to the sixth decimal. Very accurate determinations of wave lengths of unknown elements are required in order to make sure that those elements are not identical with known ones. No such identity has yet been found in the case of nebulium.

This is not all of the knowledge of the Orion nebula that Fabry and Buisson have obtained by the interferential method. By varying the distance between the silvered plates of glass, the difference of path of the interfering rays can be varied. The phenomenon of interference ceases at a certain limiting value of the difference of path. This limit is a function of the width of the corresponding spectral line and furnishes a means of determining that width. Now, if we assume that the width of a line is due to the velocity of the radiant particles, we can deduce, from the Doppler-Fizeau principle and the kinetic theory of gases, a relation connecting the width of the line, the temperature, and the atomic mass of the radiant particle. Hence, if we know any two of these three quantities we can compute the value of the third. In this way the absolute temperature of the hydrogen in the Orion nebula can be deduced from the atomic mass of hydrogen, assumed equal to unity, and the measured difference of path at which the hydrogen rings vanish. The temperature thus indicated, as a maximum, is 15,000 degrees.

Now, if we determine the limiting difference of path for the nebulium rings and the corresponding width of the nebulium line, and assume that the nebulium has the same temperature as the hydrogen, we can deduce the atomic mass of nebulium. The result is nearly equal to 3. The same process, applied to the green line of wave length 500.7, gives a value nearly equal to 2 for the atomic mass of the element emitting that radiation. It is almost certain, therefore, that this element is not identical with the element that emits the nebulium radiation of wave length 372.7.

Rydberg has been led by theoretical considerations to assume that between hydrogen of atomic weight 1 and helium of atomic weight 4, there exists two unknown elements of atomic weights 2 and 3. It appears probable that these elements exist in the nebulæ.

* From the Presidential Address of Compte A. de la Baume Pluvinel to the Royal Astronomical Society of F ance, April, 1915.

Gas Turbines Brought to Practical Efficiency

During a visit which the writer paid to the works of Brown-Boveri & Co., in Baden, Switzerland, he learned of experiments which they were making, in a carefully guarded chamber, on the designing of a commercially effective gas turbine. Trials at that time were not wholly successful, owing to the destructive effect of gases at the high temperatures of combustion on the turbine blading and similar difficulty with the valves sticking which prevented the proper operation of the explosion chambers. Recent correspondence, however, indicates that this turbine has finally been brought to a state of practical working efficiency. It is designed and operated on the impulse principle.

In the internal combustion engines of existing types, however, the cylinder is an explosion chamber and power cylinder combined, while in the impulse gas turbine the explosion chamber is separate from the power member. There is a group of bottle-shaped explosion chambers arranged radially around the shaft of this turbine. Each chamber has inlet valves for air and gas and an exhaust valve for the product of combustion. The operation bears points of resemblance to a two-cycle gas engine, and may be described in general as follows:

Air is forced into each explosion chamber in turn. The gas entry valves are then successively opened and gas is also forced in under pressure. When volatile liquid fuel is used a spraying apparatus worked by compressed air, on similar lines to the Diesel engine, is resorted to. As the explosion chambers become filled with the predetermined proportions of gas and air, the mixture in each is fired by electric sparks passing between the contacts placed in several strategic parts of the chamber. On the combustion of the charge the temperature rises sharply, with the pressure closely following. The exhaust valve in the neck of the explosion chamber is then opened and the hot gases are forced out through a conical nozzle similar to that used in the two best known types of impulse steam turbines.

From the nozzle the now cooling and expanding gases impinge on the rotor. A fan keyed on the shaft is placed at the exhaust to assist in drawing the hot gases through the rotor and accelerate the reduction of temperature. When the pressure in the explosion chamber has been spent an independent blast of air is forced through to perform the office of scavenging, as in the two-cycle reciprocating gas engine after the completion of the power stroke. In the case of the turbine, however, the time available for scavenging is longer, and with perfected design the results will undoubtedly be very satisfactory. A fresh supply of fuel is next forced into the explosion chamber and the process continues. The exhaust gases can also be used to raise steam in a small boiler, the steam being used to drive the air and gas pumps, and also for the producer.

A gas turbine would occupy only one third of the space required for a gas engine of equal power, and will average not more than a quarter of the weight; hence a wide field of usefulness will be immediately open to this machine. Even before the outbreak of war it was being considered for aeroplanes and dirigibles, and the first successful trials which come to the attention of the engineering world are likely to be in connection with military service; but such developments may not become well known until long after they have occurred. The commercial exploitation of the gas turbine will in all probability not take place until the readjustment of industry following the conclusion of peace.—By C. A. Tupper in the *Iron Age*.

Corrosion of Iron and Steel

In a paper read before the Iron and Steel Institute, England, by Messrs. Friend and Norton, it was stated that no simple answer can be given to the oft-repeated question, "Which is the more corrodible, cast iron, or steel?" unless full details are given as to the nature of the corroding media. In ordinary air gray cast iron would appear to be more resistant to corrosion than steel. When completely submerged in water, there is very little to choose between the two metals. With regard to resistance to sulphuric acid attack, the steel has the decided advantage.

The Ultramicroscope

And Its Application to Modern Biology

Some ten years ago Siedentopf and Zsigmondy introduced into the natural sciences a new method of microscopic research called ultramicroscopy. By this method it is possible to see small particles, the dimensions of which were formerly far below the limits of microscopic observation. The new method, consequently, aroused much interest.

The principle upon which the ultramicroscopic method rests can be explained by recalling the motes in sunbeams. Small particles of dust are always present in atmospheric air. We draw large quantities of them toward us with every breath, yet generally we do not see them because they are too small. If, however, direct sunlight enters a dark room through a slit, then the motes suddenly appear as if by magic.

The particles of dust are thus made visible because the sunlight on their edges is deflected from a straight line, or is diffracted, as the physicists say. Every diffraction of light produces interference. Interference causes the appearance of bright and dark rings, called diffraction rings, concentrically surrounding the particles of dust, whereby these particles appear to the eye as though self-luminous. Thus, the path of the sunbeams is seen from all sides; the pencil of rays passes through the dark space like a diffused luminous band.

The sunbeams can also be observed in a room with diffused daylight, if direct sunlight enters. They are, however, much more clearly seen against a dark background. The effect of the contrast between light and dark is thus of very great importance for their visibility.

It is in this way that Dr. O. Damm, in an interesting article in the German journal *Prometheus*, explains the use of the ultramicroscope. In discussing the subject he says:

"The ultramicroscopic method is based upon this effect of contrast. There are two essential preliminaries: first, the particles to be investigated must be under a very strong illumination; second, the illumination must be that of the dark field. The light of direct illumination gives a deceptive effect. Various persons who have investigated the subject have met these conditions by means of different devices.

"The ultramicroscope, therefore, does not give a reproduction in the exact microscopic sense, but merely a proof of the existence of small particles which have a refractive index different from that of the surrounding medium; this lack of reproductive power is its chief defect. Consequently, the ultramicroscope is hardly to be regarded as a new microscope based on a hitherto unknown principle; it is rather an ordinary microscope in which the illumination of the dark field is most ingeniously turned to account with the aid of the strongest possible light."

The efficiency of the best microscope is a limited one. When a diffraction grating, that is, a glass-plate on which fine, equidistant lines are ruled with a diamond, is examined by transmitted light through a microscope, the microscopic image, if the light is propagated in a straight line, will be similar to the object as regards the distribution of the brightness of the light. As Abbe has shown, however, on account of the diffraction at the grating, this similarity only exists if no noticeable part of the diffracted light is lost to the image. The equation for the diffraction is: $\gamma = \lambda$ sine w, in which γ denotes the length of the light-waves, λ the distance of the parallel faint lines, the breadth of the grating, and w the angle of refraction. The less the breadth of the grating, the more the diffracted pencil of rays is turned to the side, therefore the smaller the amount of diffracted light taken by the objective of the microscope. If the breadth of the grating equals the length of the light-waves and thus the angle of refraction for the first diffraction image, according to the equation, equals 90 degrees, no diffracted light enters the objective in direct illumination, and under such conditions the grating must appear at each magnification as a uniformly bright structureless surface. Consequently, diffraction sets an insurmountable barrier to the efficiency of the ordinary microscope.

In actual use, the limit of microscopic observation with direct illumination is about 1/4,000 millimeter, with oblique illumination by means of violet rays, and with the aid of a monobromated naphthalene immersion 2/100,000 millimeter. Everything below this is called ultramicroscopic.

"The ultramicroscope enables us," continues Dr. Damm, "to penetrate a long way into the domain of the invisible. According to Siedentopf, particles may be perceived with the ultramicroscope which have a diameter of about 4/1,000,000 to 6/1,000,000 millimeter. These, though, are magnitudes that approach very closely to the molecular dimensions of complicated organic compounds, in some cases even attain them. According to O. E. Meyer, the molecule of hydrogen has a hypothetical diameter of 1/10,000,000 millimeter; according to Jaeger, the molecule of ethyl-alcohol has a diameter of 5/10,000,000 millimeter, the molecule of chloroform a diameter of 8/10,000,000; according to Lobry de Bruyn, the diameter of the molecule of starch is 5/1,000,000 millmeter. Consequently, the molecule of starch must be within the reach of ultramicroscopic perception.

"Thus, the investigator has prospectively before him, in dependence on the contingent increase of the intensity of light, the ability to see in the dark field of the ultramicroscope those theoretically disclosed particles, the molecules, which seemed beyond the reach of our sight forever, and the hope of following with his eyes the play of their attractive and repellant forces. Thus, everything depends on the enhancement of the illumination. Yet the brightness of the ultramicroscopic particles begins to decline with the sixth power of the diameter. Should it prove to be possible with the aid of the ultramicroscope to obtain a deeper insight into the form and structure of matter, a positive service will be done to philosophy."

There is still a long way to be traversed before this end can be attained. Consequently, scientists have set for themselves a more modest goal, and have sought to answer the question as to the composition of vegetable and animal cells. The investigations, begun by Gaidukov, showed that the protoplasm, the nucleus of the cell, the starch-grains, and the chlorophyl-grains consist of ultramicroscopic particles. The plasma seems to be filled with moving corpuscles which look like stars in the sky at night. The walls of plant-cells are also formed of ultramicrons. As Nägeli in his micellar hypothesis foresaw, they are arranged in a definite way as fibrils and reticula.

Before the ultramicroscopic method came into use biologists frequently asked the question whether organisms existed which could not be seen even by the best microscopes, consequently were ultramicroscopic. This question is of much importance. For one, biologists would like to know to what dimensions cells can decline without losing their viability; further, there are various diseases of plants and animals, which it has not been possible heretofore to trace to living organisms, but of which it has been assumed that they possibly arise from micro-organisms, as the mosaic disease of tobacco, the infectious varicolored mottling of the leaf of the mallows, the foot and mouth disease, and smallpox.

Among the smallest known organisms are the bacteria. Many of them approach the limits of microscopic perception. Thus, for example, the bacillus of influenza is only 12/10,000 millimeter long and 4/10,000 millimeter thick; the *Bacterium Spirillum parvum* has a diameter of 1/10,000 to 3/10,000 millimeter; *Micrococcus indigofera* is said to be only 15/100,000 millimeter thick. All these bacteria were discovered and studied with the ordinary microscope, that is, without dark field illumination. Consequently, they cannot be designated as ultramicroscopic organisms.

On the other hand, according to the recent investigations of Löffler and Frosch, the exciting cause of the foot and mouth disease is of ultramicroscopic nature. The two investigators state that lymph which can produce the foot disease can be filtered two or three times through sterilized infusorial earth candles without losing its original force. If the infection were produced by a poisonous matter in solution the poison would have to be of enormous potency. Therefore, Löffler and Frosch assume that the exciting cause of the foot and mouth disease is an ultramicroscopic organism with great power of reproduction.

Up to the present no one has seen this organism, and although it must be conceded that there is a possibility of its existence, yet it must not be forgotten that some other explanation of the infection and transmission of the disease is possible. It is only necessary to recall the infectious mottling of the mallow family and the mosaic disease of tobacco. The malvaceæ *Abutilon Thompsoni* has green-checked leaves, the spotted character of which can be transferred by grafting to the pure green leaves of other varieties of the abutilon, and even to other genera of the mallow family. It has been shown by the exhaustive researches of Baur and Lindemuth on this point that the disease is never caused by an organism. Baur considers the cause of the infection to be a product of assimilation in the plant which acts upon the freshly-formed chlorophyl-grains in the formation of chlorophyl and at the same time causes them to continue the generation of this product of assimilation. Hunger, likewise, at a later date assumed the same possibility in accounting for the appearance of the mosaic disease of tobacco. The foot and mouth disease might also have a similar origin.

Raehlmann believed he had proved the existence of a whole series of ultramicroscopic organisms in putrefying solutions of albumen. In several of them typical changes of their forms were recognizable. The investigator assumes that in such cases the objects are not bacteria, but are more highly organized plasmodia. Gaidukov goes even further than Raehlmann. His investigations lead him to the conclusion that microbes of ultramicroscopic size are largely, even universally disseminated. Both opinions have been lately opposed with great energy by Molisch.

"Molisch," says Dr. Damm, "carried out the investigations in exact agreement with the statements of Raehlmann and Gaidukov. Yet he was not once able to observe ultramicroscopic organisms. The organisms which appear in the ultramicroscope as small luminous points or rods could always be observed if a microscope without the illumination of the dark field were used. Molisch's researches were continued for two years, during which he also examined numerous other preparations: river, swamp, and pond water, various animal and vegetable infusions, putrefying water containing algæ, fresh sections cut through the most varied parts of plants, etc. The result was always negative. Molisch, therefore, claims that, up to the present, not a single ultramicroscopic organism has been proved without objection to exist. If, in any case, ultramicroscopic organisms exist, in his opinion they are by no means as frequent as Gaidukov assumes. Moreover, they cannot be much smaller than the smallest organisms known up to now. In this field, therefore, he asserts, the ultramicroscope has not yielded any new results."

Adverse opinions, such as those just mentioned, have led to warnings against expecting too much from the new method. On the other hand, the ultramicroscope has proved of excellent service in the physics and chemistry of colloids. So, in spite of theoretical doubts, the hope seems justified that the ultramicroscopic method may prove a useful aid in many of the tasks of biology.

The Formation of Primitive Oceans.

Further evidence for the new physical theory of the formation of primitive oceans and continents is given by E. Belot in *Comptes Rendus*. In a former article he described how the translatory movement of the earth through the primeval nebula produced in the primitive atmosphere a circulation that chilled the Antarctic and caused there the first aqueous precipitation. Two further causes combined in this cooling effect, namely, the altitude of 3,000 meters and the gaseous expansion produced above it, the latter being similar to the cooling effect in the rear of projectiles. The author applies his theory to the alkaline chlorides, iodides, and fluorides, which are volatile between 700 degrees and 800 degrees, and which would exist in the primitive atmosphere as found at present in volcanic emanations. These salts will be precipitated before water, and in consequence the latter will be almost saturated from the commencement. If, on the other hand, Joly's hypothesis be true, that the sea was originally fresh and had acquired its salt by continental lixivation, then vegetation could not have appeared at the commencement of the primary epoch, owing to the excess of salt in the soil. Several dynamical consequences are drawn from this theory. The Antarctic erosion, as shown by the Weddell and Ross Seas, furnished material for transport by ocean currents and gave rise to barriers, now outlined by continental points, islands, etc., between latitudes 40 degrees and 50 degrees S. in the Atlantic and Indian oceans, forcing the water to the Pacific, which is consequently the most ancient ocean. This unsymmetrical water distribution, which in gaseous form was uniform throughout the whole atmosphere, was compensated by a corresponding surface movement so that the continents have oceans for their antipodes. Not only the latter, but also the quantitative relationship is true, viz., that the weight of the oceans equals that of the land above the base level—2,520 meters, and, therefore, in order to build continents above the primitive surface of the earth, the oceans have eroded a weight of material equal to their own. Finally, owing to erosion the more resistant materials remain beneath the primitive oceans, which would explain the greater intensity of gravity and magnetism at sea than upon land.

Insects' Nests*

Ingenious Methods of Construction and Curious Materials Employed

THE nests of insects are constructed of various materials, including leaves, twigs, clay, and substances secreted by the insects themselves, such as beeswax.

In the nests of European bees all of the cells, both brood cells and food cells, are alike in form, the drone cells being larger than the others. The stingless North American bees, known as Melipones, save labor by adopting a different type of construction. Like

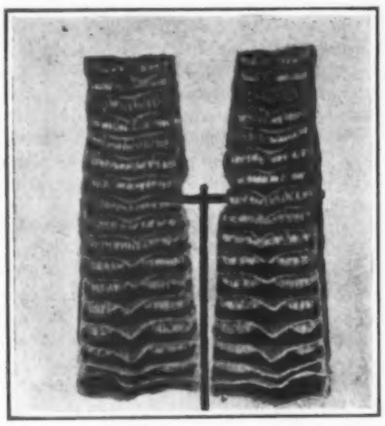


Fig. 1.—Nest of Chartergus wasp. 15 inches long.

many other wild bees, they build their nests in hollow trees, where they accumulate great quantities of wax and honey. The brood cells, which occupy the center of the mass of wax, are hexagonal, like all of the cells of common bees, but, instead of being arranged in double vertical combs and opening horizontally, they form a single horizontal comb and open upward. These hexagonal cells are surrounded by large wide-mouthed food cells of very different forms. Some of the nests are more than three feet long. If the cavity in the tree is too large, it is limited by a wall made of earth cemented by a special secretion called propolis. The same mixture is used to reduce the entrance to a size just sufficient to permit one bee to pass at a time, and even this small passage is closed at night. If the bees cannot find hollow trees they build of this mixture true nests traversed by ramifying corridors, like the nests of termites.

The large bumble-bees of tropical Africa, Asia and America bore holes in dead and dying trees. The bottom of the hole is filled with honey and pollen, one egg is deposited upon the mass, and the cell is closed with a chip of wood, which forms the floor of the next cell. In this way a column of superposed cells is constructed. When the lowest and oldest larva has attained the perfect state it makes its escape by boring through the side of its cell, and the others follow it in order through the same passage, each boring through the floor of its own cell.

* Abstract of an article in *La Revue des Sciences Pures et Appliquees*, by Prof. Sjöstedt, of the Stockholm Museum of Natural History. Translated for the SCIENTIFIC AMERICAN SUPPLEMENT.

Fig. 2.—Nest of Anaphe wasp. 7 inches long.

The social wasps surpass the bees in artistic nest building. The cells, arranged in single horizontal combs and opening downward, are composed of finely divided vegetable substances cemented by a chitinous secretion. The nests of some species are tough and elastic, while those of other species are delicate and fragile. The former are composed chiefly of vegetable hairs, the latter of inner bark or cork. The simplest nest, that of the African wasp *Belenogaster*, consists of cells connected by a common shaft, without external protection. The nest of the *Chartergus* of tropical America is composed of many stories of cells, provided with an exterior wall and a central channel of communication. New stories are added at the bottom as the colony increases. Some of these nests are 20 inches long. (Fig. 1.)

In all of the cases cited above, the nest is built by the adult insects for the protection of the larvae, but some insect larvae which lead a vagrant life construct nests for their own protection during the period of pupation. This is done by the processional caterpillars. Those of the genus *Anaphe*, which I have studied in Eastern Africa, construct a large communal cocoon in the fork of a tree (Fig. 2). Inside this envelope, which is composed in part of the insect's long hairs, each caterpillar spins for itself a silken cocoon, lined with a parchment-like tissue, in addition to the skin of the chrysalis proper. All of these insects leave the nest through a single opening, at the level of the supporting branch, but their near relatives, the *Hypsoides*, escape through individual orifices, which give the abandoned nest the appearance of a sponge (Fig. 3).

Some African wasps build small ovoid or globular nests of clay on walls, stones and trees. The nest is composed of closed cells, each of which contains a larva and about fifteen paralyzed spiders provided for its nourishment—the spoils of fierce combat in which the wasp is sometimes helplessly entangled in the web and

Fig. 4.—Scarab beetles at work.

is then devoured by the spider. But the spider, once stung by the wasp, is reduced to a state better than death for the wasp's purpose, because it precludes putrefaction.

Some insects construct underground nests for their offspring. Among these insects are the burying beetles, or dung-beetles, some of which are distinguished by wing covers of brilliant metallic colors. These beetles form balls of dung which serve either for their own food or for that of their larvae. In the former case the ball is hidden away for future consumption; in the latter case an egg is deposited in the ball, which is then buried.

On the plains of Eastern Africa, in October, the great black *Scarabeus* and other burying beetles may be seen engaged in this work. They possess a surprising faculty for discovering material, assembling about antelopes shot by hunters, though not one beetle has been visible in hours. The formation of the ball is a curious operation, in which the beetle is often opposed by its fellows. With the flat and toothed front of its head the scarab, turning in a circle, cuts out a lump of material, which, after being detached and rounded, is rolled along by the hind feet of the insect, which walks backward on its front feet. Often there is a lively scramble and a fierce struggle for the possession of the ball, which may change owners several times before it is safely hidden or buried.

In this case the combined food and shelter for the larva is provided by the mother, but some insect larvae construct subterranean retreats for their own pupation. The larva of the Cicada bores into the ground to a depth of about 16 inches, cementing the wall of the passage with a viscous secretion, as it proceeds. The food required for producing this considerable quantity of secretion is obtained by sucking the sap of roots laid bare by the boring. In this solidly walled shaft the insect can rise toward the warm sunlit surface by day, and descend at night or in cold weather.

Fig. 3.—Nests of Hypsoides wasp. The larger nest is 16 inches long.

Some ants construct their nests in the form of galls on plants. On the East African plains one often sees small, long-spined acacias which from a distance appear to be covered with black apples. These apples are hollow galls, inhabited by little ants of the genus *Cremastogaster*. If the gall is touched the ants swarm out through minute holes, emitting from their uplifted abdomens a malodorous white liquid which impregnates the surrounding foliage. At first the galls are green and solid, but the ants gradually remove the interior parts, leaving smooth-walled hollow cells, which, being riddled with holes, sound like Aeolian harps in the wind, and are known as "acacia flutes." If the eggs, larvae and pupae were placed in these shells without special protection they would be severely shaken up whenever the hard, woody galls were knocked together by the wind. This danger is averted by constructing partitions and compartments with the material removed from the gall.

Both the ants and the acacias derive benefit from this symbiosis. The ants obtain protection for themselves and their brood, while their ill-smelling secretions protect the acacias from the ravages of antelopes and giraffes.

Some of the weaver ants employ their larvae in constructing their nests, which are formed in the foliage of trees by sewing the leaves together with silken threads. (Fig. 5.) If the nest becomes torn the ants swarm out of the fissure, some of them prepared to repel the supposed enemy, others intent upon repairing the damage. If the fissure is too wide to be spanned by a single ant, a living chain is formed, each ant hold-

Fig. 5.—Nest of Australian weaver ant. 8 inches long.

ing another in its jaws until the ant at the front end of the chain succeeds in seizing with its jaws the leaf on the opposite side of the chasm. Sometimes the chain contains five or six ants, and several hours' hard labor is required to bring the leaves together. When this has been accomplished the edges of the leaves are carefully cleaned and polished. At this juncture the ants, which in the adult state possess no silk-producing glands, employ an artifice so astonishing that naturalists doubted the truth of the first account of it, brought from Singapore in 1890. Several ants emerge from the nest carrying in their jaws a larva, from whose mouth issues a stream of liquid silk, which hardens on exposure to the air. The leaves are then stitched together by applying the larva's mouth alternately to the two edges to be joined. The internal partitions of the nest are constructed in the same manner. Anatomical examination of these larvae reveals the presence of silk glands of dimensions unknown in other Hymenoptera.

Are these various and complex actions expressions of intelligence in creatures conscious of the value of the methods and of the object to be attained, or are they purely instinctive acts of animals devoid of reason? If animals were mere mechanisms, destitute of spontaneity, all the nests of a given species should be exactly alike. Now, in certain species at least, we find remarkable adaptations to variations in environment, and these adaptations may become fixed as hereditary characters, if their predisposing causes continue to act for any length of time.

The eminent entomologist and psychologist, Forel, thus summarizes the results of more than twenty years' study of insect psychology:

"All characters of the human mind can be derived from characters of higher animals, and all characters of higher animals can be derived from characters of lower animals; in other words the law of evolution is as applicable to the domain of psychology as it is to the domain of physiology."

Living Magnets*

Analogies Between Plants and Animals and Steel Magnets

If a freshly cut willow twig is planted in moist earth or sand, or even in water, numerous roots soon grow from its lower end, and branches sprout above. If the cutting is inverted before planting, a few weak roots sprout from the buried portion, but they soon wither, while strong leaf-shoots break through the earth and grow upward. Meanwhile numerous roots sprout from the part of the cutting that is now above but was below in the parent bush. These roots grow downward until they reach their proper element, the earth (Fig. 1).

Fig. 1.—Willow cuttings, sprouted in the erect position (A), and inverted (B).

The experiment may be repeated with plants of all kinds. In every case green shoots sprout from the originally upper end and roots from the originally lower end of the cutting, which botanists consequently call the leaf pole and the root pole.

The same results are obtained with root cuttings. Root and stalk obey the same law, and every plant has its root pole and leaf pole, as every magnet has its north pole and south pole.

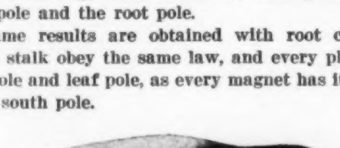


Fig. 5.—Artificially united tadpoles.

If a willow twig is cut into many pieces and these are planted separately, each piece similarly produces roots at the basal end and leaf shoots at the apical end. So, when a magnet is divided into many parts, each separate fragment shows itself to be a complete magnet, with a north pole and a south pole.

A plant is composed of a multitude of cells. If we carry the idea of polarity to its logical limit, therefore, we must conclude that every living cell has its root pole and leaf pole, and that the cells are arranged with unlike poles in contact, like the molecular magnets of a steel magnet, so that the action of free poles is manifested only near the ends.

Several explanations of the polarity of plants have been advanced, but its true cause is unknown. Two theories deserve brief mention. One of them assumes the presence of special root-forming and leaf-forming substances, which move to opposite ends of the cutting, when it is separated from the plant. No one, however, has proved the existence of such substances. The other theory supposes that the direction in which the structural material flows in the plant determines whether the new growth shall be a root or a leaf shoot. The evidence adduced in favor of this hypothesis will not bear critical examination.

The parallelism between plants and magnets goes still further. Only unlike magnetic poles attract each other, and only unlike vegetative poles grow together in a natural manner. If the freshly cut surfaces of like poles are present together they refuse to unite, or they unite with difficulty and imperfectly, often forming tumors which resemble those produced by parasites and sometimes cause the death of the plant.

Fig. 2.—Grafting and budding.
A, cleft grafting; *B*, side grafting; *C*, budding.

The polarity of plants enables gardeners and horticulturists to propagate superior varieties of many plants by cuttings planted in the earth, and of others (usually trees or shrubs) by grafting or building them on stocks of inferior sorts. In cleft grafting the trunk or a large branch is cut off, the stump is split, and the graft or scion of the improved variety, with its lower end cut in the form of a wedge, is inserted in the cleft.

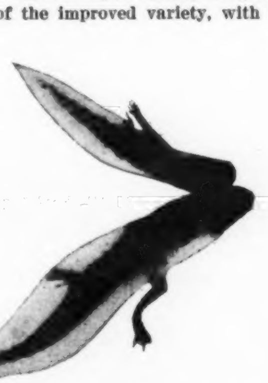


Fig. 6.—Young frogs joined by their heads.

When the stock and the scion are nearly equal in thickness, both are cut obliquely and fastened together with the cut surfaces in contact. This is called side grafting. In budding, a T-shaped incision is made in the bark of the stock, and the bark is loosened so that a small piece of bark of the improved variety, bearing a bud, can be inserted beneath it (Fig. 2). In all three cases the wounds are covered with wax and suitable bandages.

Animals also possess polarity in some degree, the head and tail corresponding to the root and tip of a plant, or the north and south poles of a magnet. In general, animal polarity is more strongly developed in lower than in higher species.

In animals, as in plants, unlike poles grow together most readily. Fig. 3 shows an earthworm composed of parts of two worms, one furnishing the head portion, the other the tail portion. The operation was entirely painless, as the worms were chloroformed. The parts were joined by means of stitches of silk in the skin. The internal organs soon united and the compound worm became indistinguishable, in appearance and otherwise, from a normal earthworm. The two parts grew in perfect proportion to each other.

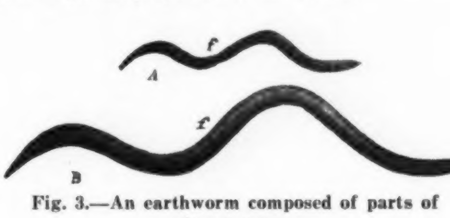


Fig. 3.—An earthworm composed of parts of two worms.

A. The worm 10 days after the operation. Length of 2.8 inches, greatest diameter 0.14 inch, junction plainly marked by a furrow *f*. *B*. The same worm 22 months after operation. Length, 5.6 inches, greatest diameter 0.2 inch, furrow scarcely perceptible.

Fig. 4.—An earthworm composed of parts of three worms.

Parts of several animals can be united in the same way (Fig. 4). Earthworms are best adapted for these experiments because of their extraordinary regenerative power. Even whole animals can be united to form "Siamese twins." Born sliced a little flesh off the under sides of two young tadpoles, pressed the wounds lightly together and kept them in contact by winding fine silver wire round both tadpoles. The artificial monster lived fifteen weeks, a comparatively long life for tadpoles in an aquarium (Fig. 5).

Fig. 7.—A tadpole composed of parts taken from two species.
A, 2 hours; *B*, 26 hours; *C*, 4 days after operation.

The movements of the double tadpole were very interesting. It usually swam on its side, with its two tails swinging almost simultaneously in the same direction. In moments of excitement, however, the tails waived laterally and irregularly, producing gyratory movements. Occasionally one component did all the work of propulsion and the other was drawn passively along.

Two tadpoles united at the back of the head developed into the pair of young frogs shown in Fig. 6. One was much larger than the other, and hopped about briskly, carrying its companion.

In the animal, as in the vegetable kingdom, parts of individuals of different, but nearly related species, can be united.

The dark front part of the tadpole shown in Fig. 7 belongs to the species *Rana silvatica*, the light colored hind part to *Rana palustris*.

* Translated from Dr. O. Damm's article in *Prometheus*.

Many higher animals show no evidence of polarity. In this respect they differ essentially from higher plants, the polarity of which is largely due to the influence of sunlight and gravitation. The root of a plant is positively geotropic and negatively heliotropic, while the stem is negatively geotropic and positively heliotropic. Polarity is apparently far more necessary to the sedentary plant than to the freely locomotive animal.

Experiments in animal grafting possess practical in addition to scientific interest, for they lead to the development of methods of replacing diseased human tissues and organs by sound ones, taken from living or dead human beings, or from animals. Skin grafting has been practised for a long time, and surgeons are steadily progressing in the transplantation of tissues. Prof. Lexer of Jena has successfully replaced the entire useless knee joint of an eighteen-year-old girl with a knee joint taken from a freshly amputated limb. Many similar cases could be cited. The art is still in its infancy, and a vast field of usefulness remains to be explored and cultivated.

Notes from a Volcano Laboratory*

"Personal Documents" in the Case of Kilauea and Mauna Loa

By T. A. Jaggar, Jr.

In the popular mind, an active volcano is supposed to be the most disorderly and haphazard thing imaginable. But when, at the suggestion of business men in Honolulu, the town of Hilo in 1912 subscribed the money to build an Hawaiian volcano observatory at Kilauea, there was evidenced a scientific spirit in the community far in advance of the popular conception. It became the function of the new observatory to study the two active volcanoes, Mauna Loa and Kilauea, from year to year as closely as possible with a view to finding out, apart from all prejudice, whether the gases and lavas come out from the earth's interior in some orderly pulsations or otherwise. The gradual growth of the science of volcanology, from an historical history of disaster, has been well begun in Italy, Japan and elsewhere since the terrible catastrophe of St. Pierre in Martinique in 1902, and the foundation of the Hawaiian Observatory was a sound step in advance. It is my purpose to show here certain orderly results of three years' watching and to urge the necessity of extending our facilities so that the summit crater of Mauna Loa will be more accessible.

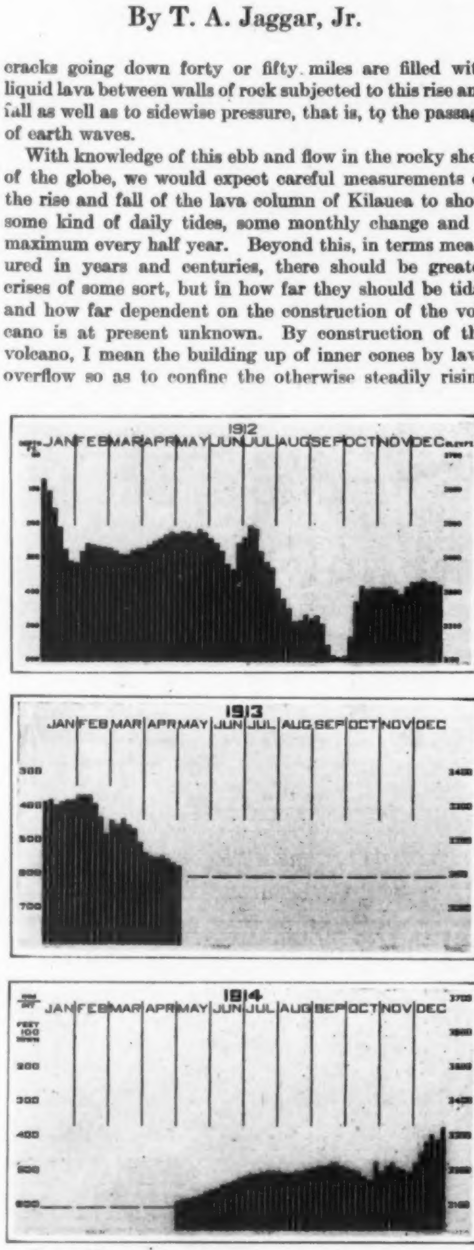
In spite of hard times and hard prospects, the scientific work on the volcano has received encouragement from the community. The Hawaiian Volcano Research Association has been organized and anyone who is interested may join and receive the weekly bulletins which tell of the progress of the volcanic activities at Kilauea. We have members in Europe, United States, Central and South America and Japan. The Massachusetts Institute of Technology is a large subscriber, and contracts to carry on the scientific work of the association. Co-workers have made important experimental studies here who have come from Italy, Switzerland, France, England and United States. We have taken part in the investigating of the great disaster of Sakurajima in Japan by sending an expedition hither.

For three years the observatory at Kilauea Volcano, under the scientific direction of the Massachusetts Institute of Technology, has recorded the rise and fall of the lava in the pit of Halemaumau, has mapped the outline of the lava pool, has noted the nature of the activity and the temperature of some of the gas vents, while the seismograph pendulums in the basement of the Observatory have written, from second to second, a story of the local earthquakes and the tiltings and tremblings of the ground, and the meteorological instruments have made similar records of the rainfall, humidity, temperature and pressure of the air.

ROCK TIDES.

It has long been known that the crust of our rocky globe rises and falls with a tide similar to that of the ocean. Like the latter, this slow creaking wave that passes through the rocks to a depth of many miles is occasioned by the pull of the sun and moon acting upon the revolving earth. The earth bulges somewhat in a zone around the equator and every month the moon moves north and south of the equator while the sun does so only every year. Each half year the sun reaches its farthest south or its farthest north, while the moon does so each half month. These great celestial swings make a squeeze upon the bulging crust of the equatorial belt over and above the normal tides, which depend upon the daily rotation of the earth, and the conjunction and opposition of sun and moon, popularly known as the times of new and full moon. There are other factors, such as the times when the sun and moon are respectively nearest to the earth, which modify the daily, semi-monthly and semi-annual squeezes which are crunching the rock crust on which we live, and a diagram showing all the complications of tidal theory and its effect at any point on the globe no one living is at present competent to construct. But from direct experiment, Prof. Chamberlain, geologist, and Prof. Michelson, physicist, of the University of Chicago, have recently proved a tidal movement in the solid earth, up and down, of about a foot twice each day and varying in amount through the lunar month and the solar year; and more than twice as great in a north-south direction as east-west. It is easy to understand how important such a movement is here in the equatorial belt of the globe, where relatively small cracks going down forty or fifty miles are filled with liquid lava between walls of rock subjected to this rise and fall as well as to sidewise pressure, that is, to the passage of earth waves.

With knowledge of this ebb and flow in the rocky shell of the globe, we would expect careful measurements of the rise and fall of the lava column of Kilauea to show some kind of daily tides, some monthly change and a maximum every half year. Beyond this, in terms measured in years and centuries, there should be greater crises of some sort, but in how far they should be tidal and how far dependent on the construction of the volcano is at present unknown. By construction of the volcano, I mean the building up of inner cones by lava overflow so as to confine the otherwise steadily rising lava column, as is the present case with Halemaumau, and complications of hot gas and congealing lava underground which may determine the relationships of Mauna Loa and Kilauea.



Courtesy of Science Conspectus

Records of rise and fall of lava in Halemaumau.

There is definitely a daily movement marked by a maximum and minimum of lava level in Halemaumau every few hours, and there seems to be a tendency to marked rising about noon and midnight, the times of maximum barometric pressure. There is also a pulsating movement which I once recorded for twenty-two hours (in January, 1913), making a measurement once an hour of the height of the lava surface. The lava as a whole was rising, but the record showed a succession of quick jumps followed by slow sinking for three or four hours, each jump happening within the course of an hour and rising to a point slightly above that of the last previous jump. This jumping movement was probably occasioned by gas accumulation and release, while the net rise in the course of a day may have been tidal. It is to be hoped that some day we shall have the means during a time of high activity of Kilauea to keep a staff of assistants at work with a transit on the edge of the pit every fifteen minutes throughout a lunar month, and thus construct a diagram showing the details of tidal movement. This would necessarily be more expensive work than is now possible.

Diagrams have been prepared to show for the years 1912, 1913 and 1914 the rise and fall of the surface of the liquid lava measured from the edge of the pit Halemaumau, which is at an elevation of 3,700 feet above sea level. The average height of the lava for each five days has been shown as a black vertical line drawn with reference to a scale of depths below the rim of the pit indicated on the side of each diagram so that the tops of the black lines fluctuate in height in accordance with the measurements. From left to right across the diagrams are monthly divisions, each month of thirty days being represented by six of the vertical lines or columns, and the fluctuation in height to the top of the columns thus expresses for each month graphically the fluctuation of the lava.

These diagrams, beginning with January, 1912, reveal on the whole a gradual sinking of the lava throughout that year and until May, 1913, when the pit became so smoky and the lava sank so low that for just one year no accurate measurement was possible. The year in question was from May, 1913, to April, 1914, when the lava was in general over six hundred feet below the rim of Halemaumau. From May of 1914 to the end of that year the lava gradually rose, but not so high as previously; and then from January 5, 1915, to the end of March, 1915, it has gradually been sinking until it is more than five hundred feet below the rim of the pit.

Examining the details of these diagrams from month to month it is easy to see that every month there is a distinct bend in the movement of the lava. The lunar month contains twenty-eight days and therefore does not check perfectly with the calendar month. Allowing for this we find that there are thirteen crises in the year 1912 about a month apart, as follows: December-January high, January–February low, February high, March low, April–May high, June low, July high, August low, September high, September-October low, October high, November low, December high. The incomplete diagrams of 1913 and 1914 show similar features, and it becomes clear from a study of these diagrams that there is a complete rise and fall of the lava column, a flow and ebb, every two lunar months. In general, rising takes place faster than falling, though this is not invariable.

We next come to a very marked characteristic of the movement of the Kilauea lava column, namely, the semi-annual high level. That this is connected with the change in declination of the sun north and south of the equator seems probable, because both the changes in the sun's angle and the rise and fall of the lava are gradual, and the quarterly culminations correspond. The 1912-1913 diagrams show high level (1911), November–January, low level February–April, high level May–July, low level August–October, high level November–January, low level February–April. The high levels are times of solstice, the low level times of equinox. This movement became so definite that it has been used during the past year for prediction, and the December rise of 1914 was expected. The prediction stated that there would be a fall in January, 1915 and thereafter, and these things have come true.

There are thus short- and long-period movements of some regularity within a single year, and these are gradually being verified by the accumulation of records for several years. The rising and falling of the Kilauea lava column is a sensitive index of the addition or subtraction of hot gases to a much larger mass of liquid deep in the earth, and is also a sensitive measure of any compressing together or opening apart of the walls of the larger lava chamber underground to which the pool in Halemaumau is merely a small window. Geologists think that the lava comes from a potentially molten substratum at least fifty miles down, and probably the passage leading down to this large mass of lava is nothing more than a crack or fissure. Kilauea has been built as a cone by the overflow of lava above this crack, and this overflow has built up a central hole and radiating flows so that the lengthwise trend of the fissure beneath is entirely masked by the mechanism of a central pit above. Squeezing to-

* Courtesy of Science Conspectus.

gether the walls of a fissure containing liquid, which opens into a small tube above, will cause the liquid to rise and fall in the tube, and something of this sort takes place when a tidal squeeze warps out of shape the whole body of the earth, be it ever so slightly. As only three years of measurement have yielded such important results, we may expect that a half century of work at the Hawaiian Observatory will create a new science. The work must go on, it must unceasingly increase in accuracy of method and completeness of record, and it must be extended to other volcanoes around the Pacific Ocean for comparative results.

LONG-TERM ERUPTIONS.

Even with the casual notes of travelers and scientific men made since the time of Vancouver's voyage in 1794, it is possible to glimpse something of the meaning of the relationship between Kilauea and Mauna Loa, and of the long-term happenings at Kilauea which are marked by tremendous cataclysms. There have been two such catastrophes at Kilauea in historic times, the explosive eruption of 1790 and the tremendous earthquake of 1868. In both cases there was collapse of the bottom of Kilauea crater, and afterward a new period of building up the bottom by means of lava overflows. We know nothing of what sympathy Mauna Loa may have shown with the 1790 explosion, but we know positively that Mauna Loa shared in every way in the earthquake and lava flows of 1868.

For Mauna Loa the 1868 crisis inaugurated lava flows at the south end of the mountain, and since that time the eruptions of Mauna Loa have happened about once in ten years, with flows alternating north and south. The 1868 flow was south, that of 1880 north; the 1887 flow was south, that of 1899 north; the 1907 flow was south and accordingly the flow to be expected from the present eruption about ten years later, say 1917 or 1918, should come from the north.

The outbreaks of Mauna Loa every ten years or so, beginning with gas-lava fountains at the summit and ending with lava flows from the flanks of the mountain, seem to mean that some great force tends to steadily push gas and lava out of the mountain, while a restraining structure, the great slag heap of the mountain nearly 14,000 feet high, confines the lava within the oven so built up, and compels it to erupt in spasms—at intervals instead of continuously. There is some reason to think that all volcanoes have passed through stages from free-flowing continuous lava emission to greatly confined gas-lava explosion.

Kilauea Volcano is not so high as Mauna Loa, and after its evisceration in 1790, the lava with many blowing cones and poolings within the crater, began to overflow and construct there a floor which was slowly built up into an inner cone; this cone-building by overflow being continuous throughout the nineteenth century until 1894 except for temporary interruptions by lateral outflow to the sea in 1823, 1840 and 1868 and possibly 1887. From 1894 to the present time Kilauea has failed to overflow the inner Halemaumau cone, and this period of twenty-one years, more than a fifth of a century, must be an important episode in the approach toward another great crisis like those of 1790 and 1868. Both Mauna Loa and Kilauea have shown diminution of volume of lava poured out from 1790 to the present time.

VOLCANIC SYNCHRONISM.

It has frequently been asserted that there is no sympathy between the activities of Mauna Loa and Kilauea. This statement seems to me a loose one, unsubstantiated by facts. If there were a deep-seated connection somewhere between the surface of the earth and the substratum fifty miles down whereby both the Mauna Loa and Kilauea lava-gas columns come together, and the mechanism of the rising and falling columns is dependent on a squeezing earth crust and on hot gas which maintains a heat circulation in a liquid subject to rapid congealing, then we are not to look for any hydrostatic balance between the two columns. We have clearly to do with an uprising stream of liquid on each side of the system, that is in Mauna Loa and in Kilauea respectively, by its own tendency to solidify above when chilled, and is maintained by the release of hot gas and lava under pressure from below. If one of the two vents suddenly split open wider and so released to the air lava and gas under pressure, the other vent might be expected to be robbed of heat and of expanding gas, and consequently to congeal and its lava to subside. It might well be that for a time, in the case of the sudden opening of one of the vents, the other vent would show a sympathetic kick or rise in the lava, followed by subsidence as suggested above. The evidence of sympathy, therefore, in the behavior of the two vents would be complex and would depend on the sizes and heights of the orifices, the source and mechanism of the heat supply, the depth and size of the connection between them and the volume and pressure of the foaming body of lava available for the particular eruption in question. This last factor is doubtless dependent on the time interval which has elapsed since the last eruption, in the case of a volcano like Mauna Loa, if we suppose the succession of eruptions to be the spasms of a steadily accumulating fluid which tends to escape.

The records of the nineteenth century are too incomplete, especially as concerns the stagnant times of Kilauea, to give us any clear evidence as to whether Kilauea lava went down when Mauna Loa lava came up and *vice versa*, as might be expected from the above analysis. The record of the last thirty years, however, suggests such a relation.

After the Mauna Loa outflow of 1887, there was revival and vigorous activity of Kilauea culminating in 1894. During this time Mauna Loa was quiet. Kilauea lava subsided and disappeared after 1894, and Mauna Loa revived in 1896 and poured out lava from the Dewey Crater in 1899. Kilauea showed a little life but at a very low level in 1900 to 1902 and Mauna Loa remained quiet. Mauna Loa became active in 1903 with outflow in 1907 and Kilauea remained quiet. Kilauea revived rapidly after the Mauna Loa flow of 1907, rose to its highest level three years later in 1910, remained high for the three years 1910 to 1912, and sank slowly as shown by our diagrams from 1912 to 1914. During all this time Mauna Loa remained quiet. In 1914 Mauna Loa revived, and at present, 1915, Kilauea is subsiding to what end remains to be seen.

The sequence of events suggests a more or less periodic eruption of Mauna Loa about once in ten years and Kilauea activity during the repose periods of Mauna Loa. These ten-year periods are probably controlled by influences of lava accumulation and release rather than by any tidal strains. It may well be, however, that in the critical time of approach to the end of a repose period that an exceptional tidal stress in the crust of the earth will act as a trigger to release an eruption. Other crises at still longer intervals in the history of these volcanoes are very likely always accompanied by sympathetic displays in both volcanoes, as in 1868 when the sympathy was unquestioned, and in 1790, concerning which the accounts are very meager; we know nothing whatever of Mauna Loa or of the earthquakes and lava flows of that time.

CRITICAL STRESS DATES.

Where there is accumulated stress underground from gas or lava pressure, it has been above suggested that the critical times of tidal squeeze, Summer and Winter, may act as trigger to release the gas or liquid and start an eruption. There are some dates when the earth squeeze is unusually strong, and these dates do not recur every year as they are dependent on coincidence of several variable relations of the sun, moon and earth. Thus either sun or moon may be at their nearest points to the earth, both may be farthest north or farthest south of the equator in their periodic swings, and they may be pulling together on opposite sides or on the same side of the earth. It is rare for all of these extreme positions to occur on the same day, but there was such an occurrence January 4th, 1912, the time of the very highest rise of the Kilauea lava column shown in our diagrams. Also on the same day the tide gages in Hawaii showed the highest ocean tide ever recorded on them. The reason was that moon was farthest north and sun was farthest south, both were nearest to the earth and the moon was full; that is, it was pulling on the opposite side from the sun. Events of the year, of the half year and the month conspired on one day to make a rare event of combination which only happens at long intervals. It can be easily understood that such a day of unusual stress on our globe would press the button to start explosion or earthquake if volcano or straining earth crust were ready to be touched off.

TYPICAL VOLCANIC ERUPTION.

Science is still very ignorant about volcanoes and about the physical chemistry of hot lava filled with gas. Laboratory and field studies are working together, however, in demonstrating that the course of typical volcanic eruptions is everywhere the same in kind, differing only in degree, some volcanoes showing dominantly explosion and gas, while others are comparatively quiet with liquid lava as their chief product. Without discussing here the complex reasons for what happens, which would take us far afield, it is generally agreed that a typical eruption proceeds as follows:

1. Unusual earthquake strain near the volcano for days, weeks or months, with an abnormally large number of small earthquakes and some strong ones.

2. A foamy lava rushes upward with a cracking open of the mountain through the central crater, the foaming being due to the gases contained in the fluid, very hot and very greatly compressed. According to the intensity of this gas pressure, the eruption may be a tremendous explosion which blows the lava foam to dust or it may be a violent foam fountain with oxidation of the combustible gases making flames. The first case is that of Sakurajima or Vesuvius, the second that of Mauna Loa. The rise of the lava foam in any volcano follows upon a longer or shorter term of rest, and in general, the longer the term the more explosive the outbreak. Like volcanoes are apt to have like terms of repose, and the length of these quiet intervals appears to be one of the distinctive characters of a given volcano, though some volcanoes are much more regular than others. Given an average repose period drawing to a close for a particular volcano and numerous earthquakes marking the underground stress, we can look for an eruption as most likely to come near the solstice, or on some date when the celestial tide strain is strongest.

3. The adjustment of gas to liquid underground, a complex relation little understood at present, next takes place through the escape of large quantities of gas in the form of bubbles rising through the liquid, and if the upper part of the lava column is in any sense a froth, then this froth or foam may be conceived to sink or settle down as its bubbles burst. The gas itself, imagined to be contained in solution in the lava far down, passes from the dissolved to the bubble stage somewhere in the depths, and there above expands and rises with dissociation and some chemical reaction which have various cooling and heating tendencies, the net result of which is volcanic eruption. Until these processes are imitated in the laboratory, science will know little about them, but the actual observation of volcanoes demonstrates without question that gas rushes forth for days or weeks after the first outbreak. This outrush may gradually decline, or it may be periodically renewed as though pulsating under alternate confinement and release. The term of gas escape before the liquid lava flows may be short or long, measured in hours or in years. There is no hard and fast line between explosive lava and liquid lava, and in a sense the lava flows from the instant that a volcano begins exploding; the transitions between explosion clouds, foam fountains, frothy flow, lava flow and the rise of stiff lava plugs is represented in all gradations in different volcanoes, and sometimes two or more of these processes are simultaneously at work in different parts of the same volcano.

4. The liquid lava rises and escapes from the volcano in some form of lava flow, and this stage is generally sharply marked as a term of days or months when the mobile melted rock is either welling up in the summit crater and higher, like a stiffening dome of very viscous slag, or the mountain rifts open along some ancient fissure and the liquid lava, perhaps spurting at first to the summit crater for a temporary display, finally makes a new crater lower down and pours a flood of melt for days or months down the flanks of the volcano in accordance with the habits of such volcanoes as Etna and Mauna Loa. The first type mentioned, with the stiff dome rising above the crater, is now known to be common in the West Indies, Aleutian Islands, Japan and elsewhere, but was unknown to geologists before the eruption of Mount Pelee in 1902. This escape of lava is the culminating achievement of volcanic eruption, that for which the eruptive process is devised in the economy of nature, and hence brings the eruption to a close by relieving the strain due to accumulation. The gases have been allowed to expand, the froth and gas-charged liquid to escape and to cool.

5. The cooling and congealing extends to a certain small depth below the crater and a term of repose ensues. Whatever the ultimate cause of the upward pushing force, be it gas pressure or the compressive stress of a shrinking globe, we know that the force is there. The lava has to escape once in so often, and the machinery of eruption adds so much new rock to the surface of the earth.

6. A new term of accumulation in the deep region begins. There may be a few small earthquakes occasioned by the settling of the rocks over the void left by the lava flow, but in general, the years immediately following a complete eruption constitute a time of unusual quiet with little activity either seismic or volcanic. By complete eruption is meant the escape of the final lava flow for a given eruptive period, for some volcanoes have recurrent flows for several years before an eruption is finished.

MAUNA LOA 1914.

Summarizing the six stages of a typical volcanic eruption, they may be briefly expressed as (1) earthquake stress, (2) gas foam explosion, (3) gas release, (4) liquid release, (5) solidification, and (6) new accumulation. Mauna Loa in 1914 illustrated the end of a period of accumulation (6), and a year of earthquake stress (1) initiating gas-lava foaming (2) in Mokuaweoweo, the summit crater, November 25, 1914, and gas release (3) took place through the summit orifices throughout December and January and probably continues at the present time (Spring, 1915), with subsidence for the time being of the lava froth.

That the approach to the solstice (December 22), and the earth's nearest approach to the sun (perihelion) about the same season induced effective stresses touching off the accumulated strain is probable. For in November there were sixty local earthquakes, at the end of the month the summit fountains broke out, and this activity endured until twenty days after the solstice, when the glow and fumes died away.

There remain yet to come in the present eruption of Mauna Loa stages 4, 5 and 6; namely, the escape of liquid lava, its solidification and the beginning of a new

Three-driblet dome: floor of Kilauea crater.

repose period. By this analysis, it should be plain that Mauna Loa is now active and must be so regarded until the lava flow comes.

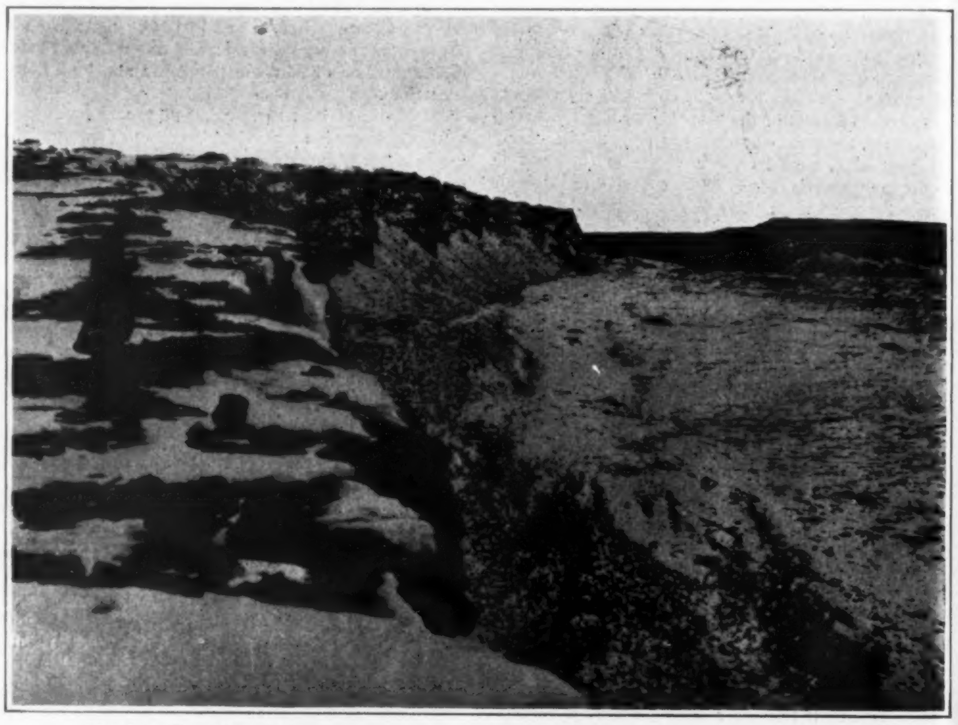
It will now be profitable to review what the Hawaiian Volcano Observatory has done in preparing for and observing this eruption of Mauna Loa. The studies of men of science who have come to Hawaii from a distance, Dana, Friedlænder, Daly, Brun, Perret, Day and Shepherd, and the work of Brigham and Hitchcock, resident here, have thrown new light on sequences, intervals and the meaning of volcanic gases, and these things are the basis of the deductions outlined in this lecture. Four of these workers have co-operated with the Observatory. The staff of the Observatory has made continuous records of the processes of Kilauea, and has visited the summit crater of Mauna Loa at least once a year.

PREDICTION.

From these records I have worked out a tentative philosophy of the two volcanoes, as herein outlined, with a view to the practical service rendered the community in securing some basis of prediction, however inadequate and faulty our first attempts may be. Mr. H. O. Wood has been studying carefully the present-day local earthquakes and the records of the terrific Hawaiian earthquake of 1868 and with me has been watching attentively the seismic and volcanic activities in their relation to the tidal and other stresses set up in the globe by the sun and moon. Mr. Wood has made a special study of the theoretical effects of the declination of the sun and moon north and south of the equator. From all these studies of records of the past, records of the present and of the processes of physics and astronomy, it became possible to foresee that Mauna Loa would have a summit outbreak between 1911 and 1915, that it was most likely to come near June or December, and this much has been verified in 1914. By similar reasoning there remain the as yet unverified expectations (1) a very low level of the lava of Kilauea; (2) a lava flow from Mauna Loa, probably within four years and most probably in not less than three years; (3) the occurrence of a short-lived summit outbreak before the flow; (4) the time of this outbreak probably near June or December, this combination making January or July of 1918 likely times for the eruption to culminate; and lastly, (5) the lava flow should break out from a vent on the north side of the mountain, probably somewhere above the Dewey Crater of 1899. All this sounds like unwarrantably precise prediction, but the basis for it has been explained above. To such extent as such prediction proves useful and leads to proper preparation and precaution, it is justifiable.

In expectation of a coming eruption it was desirable for the Observatory to have a station on Mauna Loa occupied frequently for purposes of recording temperatures of fumaroles, local earthquakes, weather conditions and any other phenomena that might bear on the approaching outbreak. But it early became evident that this idea could not be realized with the funds at the disposal of the Rresearch Association. Mauna Loa is a vast desert waste without water and rising to an immense height. Every expedition to the summit exhausts the energies of the men and animals employed, and the animals are frequently crippled and have their legs cut by the rough block lava. Consequently the ranchers will not rent good animals at any price, and as there is no shelter on the summit, little water, no feed, violent winds and low temperatures, the men who can with difficulty be induced to go and act as guides or packers, object to remaining over night. The wages paid them and the hire of animals are high. All of this means that it costs several hundred dollars in order to take an unsatisfactory trip to the summit, see the crater, and return before any real scientific work can be done and even before the party is acclimated to the unusual altitude. In the winter time there is deep snow on the summit plateau, and snow flurries or violent thunder storms with heavy gales of wind may occur at any season and make havoc in a camp of tents. There is no soil, so ordinary tent pegs cannot be used, and there is no flat ground on which to sleep. There is no fuel of any sort and there are no hillocks or valleys to offer shelter. The crater Mokuaweoweo is surrounded by vertical precipices from three hundred to eight hundred feet high and the floor is accessible only by arduous climbing. The area of exploration for proper study of hot vents whence lava flows may issue, and of the seven or eight summit vents (pits and cones), including the great crater is fully twenty miles long by three wide, not including the separate area of flows in Kau to the south thirty miles away. It will be seen from this that Mauna Loa presents a problem of extensive exploration under difficult conditions and is not like Kilauea in possessing a single lava pit conveniently accessible.

The most that the Observatory has been able to do, therefore, in dealing with Mauna Loa during its repose was to send an expedition to the summit once each year and to record the observations of other travelers whenever such were available. Observatory expeditions visited Mokuaweoweo in August, 1912, and October, 1913 and no unusual phenomena were noted, the only activity being very slight vaporing from cracks both in the bottom of Mokuaweoweo and in outlying fissures. These steaming fissures extend both northeast and south from



North walls of Mokuaweoweo, the summit crater of Mauna Loa, December 15th, 1914.

Mauna Loa eruption, November 27th, 1914, third night of eruption, from camp at Puu Lehau.

Technical station, north edge of Halemaumau lava pit, Kilauea volcano.

Lava whirlpool, February, 1913.

the crater, the directions in which large rifts trend down the mountain along lines of historic lava vents.

COURSE OF PREMONITORY ERUPTION.

In 1914 the Whitney Laboratory of Seismology in the basement of the Observatory, equipped with seismographs, registered groups of earthquakes from time to time in seismic spasms, and reports came from Kau and from the ranchers on Mauna Kea of sudden strong earthquakes in the line of the axis of Mauna Loa's greatest length. In November, 1914, the registration of about sixty earthquakes in three weeks, the greatest number ever recorded in like time since the instruments were set up, greatly stimulated our attitude of expectancy. On November 25th, 1914, about 12:45 P. M. the instruments showed prolonged earthquake movements of an unusual character, and at the same time cattle herders on Kapapala Ranch saw thick fume clouds puff up suddenly above the summit crater of Mauna Loa. After that the earthquake activity diminished.

The eruption became visible from the Observatory as darkness approached, November 25th, and photographs were made of Mauna Loa from the vicinity that night and on succeeding days and nights. These photographs show the column of glowing fumes, the glow diminishing rapidly after the first night.

November 26th I started for the summit by way of Kona, being unable to get men or horses for the Papapala trail in Kau. I reached the summit area in a blinding sleet storm November 28th and was unable to do any work on account of the storm. Fortunately two young men from Kau, Messrs. Forrest and Palmer, pushed their way to the summit on the previous night, November 27th, and furnished the Observatory with a sketch map and notes. They saw ten or twelve fountains of lava along a north-south rift in the bottom of the crater, one of these in the southern part being between three hundred and four hundred feet high. December 2nd, Charles Ka was sent to the summit by the writer and saw only

Kilauea, Mauna Loa and the Moon, November 25th, 1914.

Strong motion seismograph, Whitney Laboratory of Seismology.

four fountains. Similar conditions were noted a few days later by Messrs. Baker and Bowdish, and on December 15th, an expedition from the Observatory reached the summit on the Kau side and saw only one large fountain about one hundred and fifty feet high and a few small ones. These were photographed, but conditions were too stormy to permit of an extended stay on the summit.

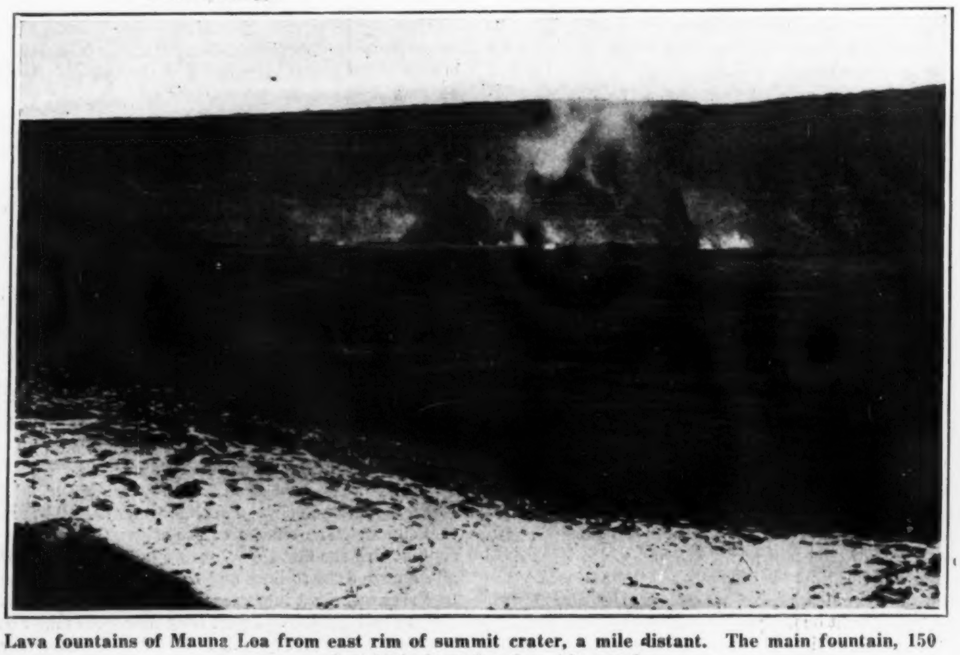
Throughout December a watch was kept at the Observatory on the fume column over Mauna Loa. It was occasionally photographed and it persisted until January 10th, 1915, showing a line of bluish fume by day and a dull glow over the mountain at night. After that date it disappeared, the fountains probably subsiding and the lava solidifying.

PREPARATION FOR FINAL CRISES.

The Observatory has a difficult and expensive task before it if it is to make adequate record of the spectacular closing stages of this eruptive period of Mauna Loa. We have learned a useful lesson of the futility of attempting a scientific siege of the crater fortress in winter-time without houses built in advance to shelter men and animals. Such houses ought to be built of stone, both at the summit and on the north flank of the mountain near the probable site of the expected flow. The escape of the liquid lava after the months of temporary repose which we are now living through will begin with more fountains at the summit, and with a slight earthquake prelude to warn us we ought to be able to have photographers ready to make pictures of the fountains at their highest. A probable time for this outbreak is about December, 1917, when the summit will be cold and snowy, but it may come sooner.

The next stage will be a lava flow from a lower vent, probably six or eight miles to the northeast of the summit crater. A secondary camp should be prepared in this neighborhood.

Lake of molten lava, February, 1913, interior lava pit.



Lava fountains of Mauna Loa from east rim of summit crater, a mile distant. The main fountain, 150 feet high, is under the white smoke.

The German State Railroad Lines*

A Most Important Factor in the German Campaigns

By Frederick William Wile

The war has been called, at various times, the "trench war," the "motor war" and the "shells war." But, as far as Germany and the German armies are concerned, it is a "railroad war," pure and simple. The amazing ability of the Kaiser's staff and field marshals to fling not only regiments, brigades and divisions, but entire army corps and even whole armies, from East to West and back again from West to East, as emergency requires, is due exclusively to the marvelous system of state-owned railroad lines which honeycomb the fatherland from end to end in all directions. When the history of the war is written the achievements of German railroad men will deserve to be inscribed in letters of red, for the triumphs of the Teuton legions in both the western and eastern theaters of war stand to their credit no less than to the credit of the engineers who built the deadly 42-centimeter howitzer or the strategists of Berlin, who have so skilfully directed the activities of the mighty German war machine.

When regiments which were fighting in Flanders, April 1st, are next heard of in Southern Galicia, April 15th, or when Germans who were resisting the onslaughts of Joffre's Frenchmen around Arras late in June, pounded at Warsaw on the 4th of July, it means that the lines of communication at the command of the German military authorities have approached something resembling mechanical perfection. We of the United States can perhaps somewhat visualize the problems the German railroad authorities are solving every day if we conjure up the vision of our own country resisting invasion, let us suppose, simultaneously in the Southwest —Texas—and in the Northeast—Maine. The distances with which the German railroad staff must deal are not, of course, as magnificent as those which separate Bangor from Galveston—all Germany is not as large in area as Texas alone—but Germany has expanded, temporarily at least, since last August, for she now occupies five-sixths of Belgium, 25,000 square miles of France and 30,000 square miles of Russia.[1] Her railroad system to-day contemplates an area, one of whose farthermost eastern points is Libau on the Baltic coast of Russia, and which stretches to the west of Belgium coast of the Channel, and internally to within 50 or 60 miles of Paris.

Put in American terms, the Kaiser's railroad strategists have to concern themselves with an area which embraces, roughly, the states of Ohio, Michigan, Indiana, Illinois, Iowa, Kentucky, Missouri, Wisconsin and Tennessee. I am sure that many an American traffic manager will acknowledge that the job of switching a couple of million armed men, with full artillery equipment, back and forth, incessantly, week in and week out, through territory of such ramifications, represents as big a piece of "railroading" as was ever tackled. I heard H. W. Thornton, the gifted and popular American general manager of England's Great Eastern Railway, tell an after-dinner audience not long ago that American traffic managers think they are handling "some traffic" when they successfully deal with a national convention, an Epworth League conclave or a G. A. R. encampment.

I present herewith the official narrative of "The Railway War," as prepared for publication in Germany by the great general staff. It is necessarily somewhat stilted in form, in the English translation, but complete idiomatic rendering of the facts in our own language is almost impossible:

"THE RAILWAY WAR."

"In order to obtain a survey of the preparations for the 'Railway War' one must remember the conditions in Germany during the critical days at the beginning of August, 1914. It was the holiday and tourist season. The large maneuvering grounds in every military district were filled with troops. The freight traffic was normal. Everybody believed till the last moment that peace would be maintained; moreover, war preparations could not, for political reasons, be carried out by the railways.

"War was declared on August 2nd. Everybody who was away hastened to the railway to reach home before the movement of the military transport began. Relatives visited their sons and brothers to take leave of them before they left for the front. The troops taking part in the maneuvers were sent back to their garrisons as quickly as possible. The mobilization of our armies had to take place partly in the western industrial district. Thousands of long military trains had to be despatched there. By this time the railways had to be cleared of the large number of loaded and unloaded freight cars in order that there might be no hitch in the forward movement.

"At the same time other transport movements began throughout the entire fatherland. Long trains of empty cars and lines of locomotives coupled together were sent to those places where, after careful consideration, cars and engines were greatly needed at the beginning. It is easy for anyone to understand the reason for all this railway traffic. First of all, there was the transport of millions of reservists and 'landwehr' men to their respective posts; then followed the transport of provisions and material for the troops and the armaments for the fortresses. In the districts of Germany which provided the horses, trains ran at specified times in every direction where the full complement of horses was needed as against the number under normal conditions in time of peace. Long trains filled with meat proceeded to the army preserving factories from the districts providing cattle. Finally, from the very beginning of the war there was a constant flow of coal trains from the collieries to the naval ports.

"A very few hours after mobilization there was the first great rush of troop trains. These were filled with men bound for the frontiers in order to guard them against enemy invasion. From day to day this traffic grew until our armies stood at the frontiers and numerous depots behind the first line of troops were filled with provisions, ammunitions, etc. This was, indeed, a great traffic in Germany! The movement of transports was carried out without a hitch. How easily might a very serious accident have happened at any one place on our vast railway system, through human neglect or by criminal hand, which would have seriously delayed the arrival of troops at the frontier! The railway authorities had, therefore, in their primary preparations to take into consideration our geographical position and see where the most vulnerable positions lay. In time of peace trial trains were run to these various positions, so that if war broke out there should be no hitch in the transport of troops. Preparations were made, therefore, for all eventualities.

"The organization of the military railways has already proved successful during the present war. When the commander of a force on the march receives news of the enemy's whereabouts and has to proceed elsewhere, trains are in instant readiness to take him to the scene of operations. The ability of the officers and employees organizing the transport of troops by rail materially contributed to our great successes on the eastern and western frontiers, but their greatest reward was reaped in the latest victories in Galicia.

"The essential condition for the prompt transport and mobility of troops by rail is to have at one's disposal a well-developed railway system. When the mobilization of our armies to the frontiers was complete and the forward march had begun, the chief of the railway section, as 'Chief of the Military Railway Organization,' and his staff proceeded to the field with His Majesty, the Kaiser. From the day of mobilization the relations of the so-called 'military railway authorities' with the German railway administration proper were completely changed. Numerous railways in Germany have since then been amalgamated with the 'war section,' that is to say, the various individual railway administrations are now subject to the orders of the 'Chief of the Military Railway Organization,' in respect to everything relating to the running of trains. This chief issues to the railway commando ('working notices') for regulating the war traffic. He has also at his disposal for this work the machinery of the railway section of the great general staff in Berlin.

"To the German railway system were soon added the railway districts in conquered territory. Our troops penetrated very quickly far into the enemy's country, yet, on practically all battlefields the enemy still found time to blow up most of the large bridges and numerous tunnels before retreating. Our railway tracks had, of course, to follow very closely behind the advancing armies, so as not to impede their forward march. This required the prompt repairing and putting into working order the enemy's dismantled railways. To this end, when mobilization took place, two military railway administrations were forthwith formed to organize railway traffic in the conquered districts exactly similar to railway administrations in the fatherland itself.

"One of these two administrations waited at Aix La Chapelle (Germany) for the time when it could proceed to Belgium The officers of the railway regiments accompanying the first line of troops immediately reported all damage done to lines and buildings entirely deserted by the enemy right into the districts of Hasselt, Louvain, Namur and Marloie. Apart from numerous minor damages, such as tornup rails, overturned engines, etc., thirteen bridges were found blown up, while a tunnel was blocked with several engines which had been made to telescope one another at full steam. Telegraph and telephone wires had been destroyed and all instruments in the stations were rendered unserviceable. Moreover, the railway roadbeds in Belgium in most cases were in a sadly neglected state and the rails were bad. Very often the sleepers broke under the weight of our engines.

"Here our regular railways troops had to commence work. They labored with almost superhuman effort so as to facilitate the bringing up of provisions and ammunition for the advancing armies. Very often long troop trains in close succession had to be brought over these lines, after one line had been cleared, and the working of the stations was taken over by railway officers with a few men. For instance, never before had a German engine been west of Liege until the first train filled with German troops going to reinforce their comrades fighting hard around Brussels ran into the station and had to proceed to Louvain. The lines between Liege and Louvain were repaired one at a time. Staff, there was none. The telegraph and telephone communications between the stations had not yet been restored. Nevertheless, train after train proceeded to Louvain and the empty trains returned the same way. Although the trains were fired on from the houses by the infuriated population and continual cowardly attacks were made, the troops were brought up in time against the enemy and could still participate in the deciding victory. The repairing and putting in order of the railways proceeded little by little. On September 1st, the military railway administration arrived in Brussels and proceeded to Lille toward the end of October. The last-named administration was taken over by newly-formed railway commandos in Liege and Brussels.

"To the south of Military Railway Administration No. 1, Military Railway Administration No. 2 was set up on August 20th in Ulflingen; on August 25th at Libramont and on September 4th at Sedan.

"A newly-formed railway commando followed in Luxembourg. The district covered by these various railway administrations was in time so extensive that a third was pushed forward between them, controled from Charleroi. In the East, presently, a railway commando was set up in Lodz for the conquered districts of Russian Poland.

"All these authorities are organized by the military administration. The railway traffic is essentially of a military nature and is carried on in the districts close behind the front by railway troops; and, farther in the rear, by ordinary individuals transferred from the German railway administrations.

"The constructional operations of the railway troops consisted during the first months of the war chiefly in restoring damaged railway buildings so as to provide as quickly as possible complete railway communications for the army. New lines were laid where the military authorities needed them most or where our railways had no extensions in the conquered territory. Owing to the unfavorable country and the bad conditions of the roads after such a wet winter, we were obliged to construct a railway system comprising innumerable small 'field railways' so as to bring up ammunition and provisions to the particular place where our troops were located.

"In the place of emergency bridges we had to build later bridges of a permanent character so as to give greater security to the ever-increasing traffic. These operations at the seat of war were carried out by the railway troops and farther back by private German firms.

"During the course of the war up to the present, 104 large bridges have been built, 8 tunnels restored and 14 lines opened to traffic. Owing to increased number of lines over 160 stations have been enlarged for the purpose of loading and unloading; also numerous crossover points have been built.

"The following table will give an idea of the development of this military traffic in the enemy country conquered by us with the exception of the Russian lines bordering on East and West Prussia, east of the Vistula:

TRAFFIC IN THE CONQUERED RAILWAY TERRITORIES (BELGIUM AND FRANCE) FOR THE MONTH OF APRIL, 1915.

(In round figures.)

1. Distance in Kilometers at the end of the Month:

	Single Line.	Double Line.	Total.
A. Used by military	3,000	4,100	7,100
B. Leased	450	150	600
C. Not in use	550	20	570
D. Not restored	90	20	110
E. Under construction	400	15	415
Totals	4,490	4,305	8,795

* Railway Age Gazette.

[1] This article was written in London July 3.

2. Traffic Management:	
A. Traffic officials	75
B. Engineers	25
C. Workshop officials	10
D. Stations occupied	1,200
E. Workshops	70
F. Gasworks	55
G. Power stations	350
3. Benevolent Institutions:	
A. Isolation hospitals	20
B. Bath establishments	130
C. Hospitals	35
D. Red Cross establishments	30
E. Dormitories for railway staff	135
F. Convalescent homes	5

"In considering the above table one must remember that only eight months have elapsed since the railways were taken over under the conditions described previously and the public passenger and freight traffic is still in its infancy. The railways can now, no doubt, respond more efficiently to the demands of public traffic."

The Efficiency of Explosives

At the commencement of the present European war, reports were circulated of a new French explosive having a terrible destructive effect, much greater than anything known. Experiments with this explosive, carried on in the Bois de Boulogne, are reported to have shown it to have frightful effect on every living thing within a distance of many yards. The report stated that the invention of this explosive, and the details of its ingredients and manufacture, were kept in strictest secrecy by the French.

In an article in *Prometheus*, Dr. Alfred Stettbacher calls attention to the fact that, although many months have elapsed, no disastrous effects from this new explosive have been evident; and he proceeds with an essay on the mechanical energy of explosives. He questions whether, even in the extremely advanced state of knowledge of explosives, it is possible to develop one so powerful that it might, for instance, wreck a fortress, or destroy several city blocks, when a bomb containing a few pounds of such explosive was dropped from an airship. He calls attention to the fact that, although numerous compounds have been invented, none has a disruptive power greater than Nobel's blasting gelatine, or "dynamite."

Dr. Stettbacher proceeds to explain that the efficiency of an explosive depends on several widely different factors. He says: "We shall have to call to mind a few important characteristics of explosives. The value of an explosive lies in the property of disengaging the largest possible amount of energy in the shortest possible time, and this energy must be released by some outside impulse, such as heat or percussion, or by a detonating cap. The energy of all commercial explosives is the energy of combustion, and the effectiveness depends entirely on the rate of production of this energy. Explosion is only a very rapid combustion process, and the difference between an explosive and fuel is solely in the rate of combustion." In the following table is summarized the heat generated by the explosion, energy in kilogrammeters, velocity of detonation, and relative value as an explosive of various substances.

Explosive Compound.	Heat of Explosion in Calories.	Work in m kg.	Detonation Velocity m. per Sec.	Relative value of work capacity.
Blasting gelatine	1,640	700,000	7,700	100
Nitroglycerine	1,580	670,000	......	96
Picric acid	810	345,000	8,183	49
Trinitrotoluol	730	312,000	7,618	44
Black powder	685	290,000	300	41
Hydrozoic acid	1,440	612,000	very high	87
Lead nitride	364	155,000	" "	22
Chlorid of nitrogen	316	135,000	" "	19
Fuel.				
Crude oil	12,000	5,100,000	......	730
Coal	8,000	3,400,000	......	490
Wood dry	3,500	1,480,000	......	210

Explosion is an exothermic process. On decomposition of an explosive heat is liberated. The explosive is transformed with great rapidity into gases, which increases their volume a thousandfold and by their kinetic energy shatter any substance in the vicinity. The velocity of decomposition may be called the velocity of detonation (as given above). For instance, in the case of picric acid, it is more than 8,000 meters per second, so that a cube of picric acid, the length of the side of the cube being 10 centimeters, requires for its gasification not more than 1/80,000 second. Such an explosive as this is called "detonating," as compared, for instance, with ordinary gunpowder, which gasifies at the rate of only 300 meters per second. Picric acid gasifies so suddenly, that if it is placed in the open air on any support, the overlying air not being able to escape, acts like a solid, and the support is wrecked.

The ordinary commercial explosives contain enough oxygen for complete combustion. But there are other explosive compounds, free from oxygen, co-called endothermic explosives which, in their formation from the elements, absorb heat, and hence are capable of performing mechanical work when decomposed. These are the most violent explosives. They have a very high detonation velocity, but their effect is limited to a very small area. For instance, hydrazoic acid, one of the most disruptive substances known, causes the greatest conceivable destruction within a very narrow range, pulverizing all substances in the immediate vicinity to microscopic dust, although at a slight distance from the explosion center the effect of the explosive is negligible.

The greater the detonating velocity, the greater the local pulverizing effect. For instance, picric acid when used in shells produces such small explosion fragments that the result is ineffective; whereas trinitrotoluol, having much smaller detonating velocity, produces much coarser and more effective shell fragments.

In the same way, ordinary black powder has only a low velocity of detonation. Its effect as a disruptive is therefore low, and as an explosive it is relatively inefficient. The energy is rather propellant than shattering. When we consider fuels we find that the explosive as well as the propellant power completely disappears. The energy being very slowly released is incapable of producing kinetic changes.

An explosive should, therefore, not only be capable of producing a large amount of energy, but should have a high velocity of detonation; but when the velocity of detonation is greater than a certain limit, the effect of the explosion is localized; and while it produces complete pulverization of material in the immediate vicinity, the range of the disruptive action is limited. Hydrazoic acid, for example, on explosion transforms its latent energy into mechanical work in the most perfect manner, but the consequences of the explosion are unimportant.

Picric acid, detonating much less rapidly, does not pulverize every material in the immediate vicinity, but shatters everything into coarse fragments over a much wider area, and has a propellant effect on the coarse fragments thus produced. The result in warfare is correspondingly much more advantageous. The change from latent energy into mechanical work is not so perfect as with hydrazoic acid.

In the case of black powder the shattering effect is much less, but the propellant power greater, and a great part of the energy is wasted in the production of useless heat.

The maximum practical effect from our high explosives has been attained. The only method of obtaining more effectiveness is by concentrating more chemical energy in our explosives. This is unfortunately impossible with our present knowledge. We are able to manufacture explosives of any degree of sensitiveness, to modify their explosive power at will, yet we shall probably never improve on our most efficient explosives, even if we should hunt through the whole series of organic compounds and by nitration, peroxidation and the like obtain the ideal compound for explosive use.

Chemical energy is constantly being formed and reformed. In this process combustion takes the greatest part, even in organic life. The exploding mine which sinks the battle-cruiser, the roaring gas engine which swiftly turns the aeroplane propeller, the storage battery which sets the electric motorcar in motion, all receive their power from the chemical process called oxidation.

No form of energy greater than that arising from chemical combustion is known at present, and no method of accumulating potential energy has been discovered which is more efficient than its storage as chemically potential energy.

Up to the present time no substance has been discovered which will store energy and liberate it more efficiently than it is released by oxidation.

Perhaps the time may come when the chemical inertness of argon may be overcome just as we have succeeded in overcoming the inertness of nitrogen, and the vast stores of this gas in the atmosphere may be made available in explosives. Such process may require such a production and storage of power as is now inconceivable.

Perhaps radium, distinguished for its practically inexhaustible energy content, may in time be developed as a power storage material. The concentration of energy in this substance surpasses all calculation. One gramme of radium develops 1,030,000 calories per year, this quantity of heat being largely given off through the formation of a radio active gas which ultimately turns into helium. The radiation of power from this marvelous element, radium, is so great that it has been estimated that, from the supposed quantity contained in the earth's crust (and the quantity is disappointingly small), sufficient energy may be liberated to cover the loss of the whole earth by radiation of heat. Were it possible to liberate at once all the energy stored in one kilogramme of radium, such an explosion would result as would minimize such a catastrophe as the volcanic explosion of Krakatoa.

It may be that radium embodies the history of the earth's energy from the time when the earth, a glowing fire ball, was thrown off from the sun, and in solar-like fire display, radiated immense quantities of energy into the world-space. Now that our planet is old, and at a temperature only 300 degrees above absolute zero, the temperature of motionless rigidity, it may be that we are kept alive by this substance, warm ourselves by its emanations, and wonder at the exhaustible quantity of energy left in this element. This slight remainder of the original energy of the earth, in the formation of which the highest solar temperatures and solar powers participated, may indicate to us how insignificant the energy of the earth is as compared with that of the universe.

It appears as if our planet had arrived at such an age, and had such slight stores of energy remaining, that the best technical appliances can produce only a slight effect in power utilization. For example, science has not succeeded in producing temperatures greater than 4,000 degrees, either by a chemical or an electrical method. This temperature is far below that of the sun (6,000 degrees).

From all these considerations, we may conclude that to each cosmic range of evolution belongs a special form of energy which corresponds to the nature and equilibrium of things. It would be contrary to nature and the law and order of the universe if there could be produced on this planet, in addition to the natural energy now present, artificial power like that controlling matters on our sun or on Sirius. Even without this, our globe has movement and variation enough.

Man's True Thermal Environment

Following Dr. Hill's article on healthy atmospheres in *Nature* of April 22nd, a letter appeared in *Nature* of May 6th under the above heading, which suggests that too narrow a view has been taken of this important subject. Dr. Milne writes from a place where man exists in spite of the climate, and no doubt the robustness of the local race is largely due to generations of selection under rigorous conditions that are only overcome with the aid of ponderous clothing and heated dwellings. At the outset we should inquire as to the thermal conditions that existed at the birth of our race. No doubt man soon learned to keep himself warm by artificial means, but he appeared first in association with a fauna almost tropical in character. It is in tropical regions that our race exists to-day in comfort with little or no protection and in spite of many adverse organisms that are also favored by warmth.

What results would Dr. Milne's psuchrainometer give us in these places? For it is of importance if figures of any value are to be obtained that the methods should be generally applicable to habitable regions. It is not remarkable that methods bred in an extreme climate must fail in quite congenial regions but where the air temperature is often over 38 deg. Cent. and sometimes exceeds 45 deg. Cent. Here, no doubt, Dr. Milne's ingenuity would produce a metapsuchrainometer to tell us what must be taken from a body to keep it at blood-heat. We should be the richer for a valuable device, but our knowledge of man's true environment would not be much advanced.

Meteorologists have succeeded very well in obscuring the significance of the wet-bulb temperatures by wrapping them up in terms of relative humidity. The relation of the dry- and wet-bulb reading, besides giving us the potential cooling power of the atmosphere as it affects a moist surface, enables us to arrive at the absolute humidity and the specific heat of the air. This last factor no doubt varies considerably with the moisture content, and must be of importance in the convection affecting the heated body of the psuchrainometer.

Dr. Milne's ψ only takes into account the air temperature, specific heat and velocity, provided radiation effects are constant. It cannot be taken to represent the whole environmental effect, which depends also on the power of the air to take up moisture. The katathermometer figures appear most promising in this respect, but the present form of instrument is probably not completely suitable for hot climates.

Khartoum, May 26th. G. W. Grabham.

Investigating Radium Ores in Canada

Samples of radium-bearing ore from British Columbia have recently been examined by the Mines Department of the Dominion of Canada. The quantity of radium contained in the ore has not yet been announced, but the examination is said to have revealed sufficient radium to make the test of special importance. Magnetite is one of the minerals regarding the possible production of which in Canada the Department has been asked to report, since the supply from Europe is cut off. The very best magnetite is known to exist in British Columbia in large deposits, but they are at present too far from transportation routes to make mining and working the ore practicable or profitable.

Signaling on Railway Trains in Motion—I*

Various Systems of Engine Cab Signals Used in France

THE subject of increased safety in railroad travel is one that never loses interest with the public and is the text for much discussion by the newspapers and by the various Commissions, both State and National, to which affairs relating to the railroads have been committed. Possibly this concentrated attention is somewhat due to the growing feeling that professional financiers are not the most desirable class of men to be entrusted with the control of the technical affairs of railroads, and it is wholly in this direction that the safety of the passenger and the improvement in service lies.

Although but one of many elements contributing to the safe operation of trains, the question of signals has always been a popular one with the public, and consequently with the railroad management and the inventor. At this time attention appears to be concentrated on systems for signaling conditions on the road ahead to the occupants of the engine cab of trains in motion, and ready have to look out for, and that the tendency is to so divide their attention that neither the cab signals nor the outside block signals receive sufficiently careful attention, and in the case of audible cab signals there is a liability to place too much dependence on the signal whistle or bell, to the neglect of the primary block signals. The result of these complications is claimed to be that the multiplicity of safeguards provided neutralizes their object, which is to eliminate the human equation that is so frequently the cause of accidents in spite of the best system of signals.

In America the tendency in investigating auxiliary systems of signals is to provide some kind of positive control that will stop the train in case a block signal is overrun. These are the various forms of train stops, and here the difficulties to be met are the mechanical one of providing, first, a device that will not be broken or disarranged by the impact of fast-moving trains, and signals, which are being tried on the road he controls.

The fixed ramp is an apparatus which is set in the center of the track, parallel to the rails at a distance from the signal, varying, as the case may be, from the foot of the signal itself to 200 meters (about 218 yards). Fig. 1 is a diagram of the electric circuit.

The ramp consists of an oak beam *A*, Fig. 2, 2 meters long (6 feet 6¾ inches), resting on two wrought-iron supports *BB'*.

The oak beam, which has been soaked in boiling linseed oil to preserve and insulate it, carries a cover-plate of brass resting on small wooden bushes or porcelain washers, and firmly screwed to it. A stout square of copper, which is riveted to the plate, is connected to the wire from the battery and lodges in a hollow cut into the wood, and closed by a small galvanized-iron plate.

If the speed of the train exceeds 50 kilometers (31 miles) per hour over the fixed ramp two such ramps

FIG. 1.—*Diagram of Electric Circuit.*
Full lines show connexion from signal to blow whistle.
Dot and dash lines show connexion from engine to warning bell.

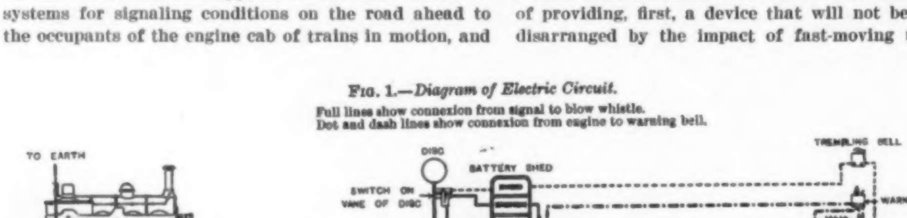


FIG. 2.—*Fixed Ramp or "Crocodile."*

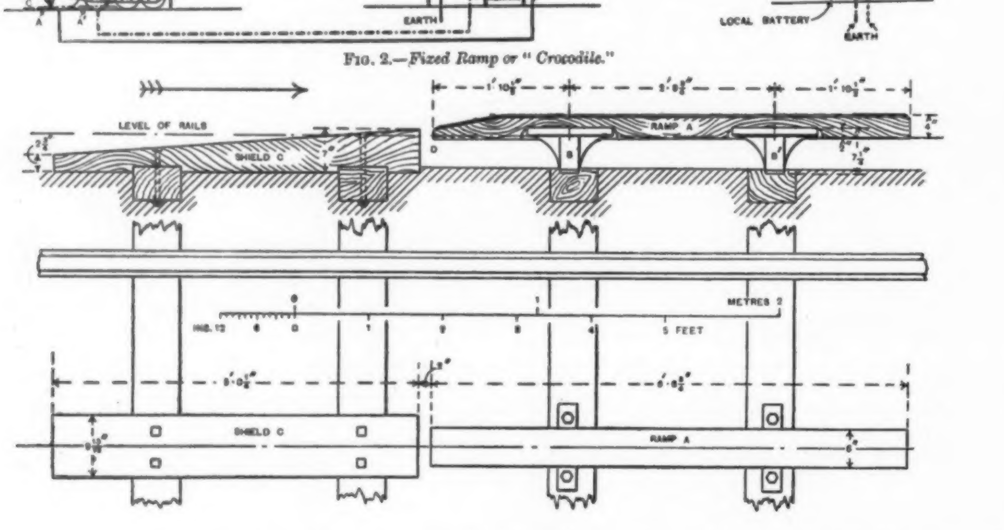


FIG. 3.—*Gauge for Ramp.*

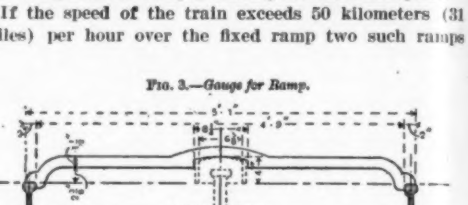


FIG. 4.
Electrically Operated Whistle.

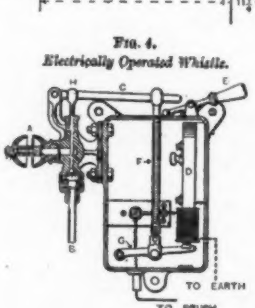
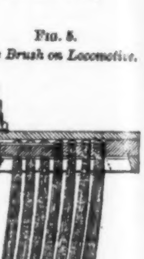


FIG. 5.
Wire Brush on Locomotive.



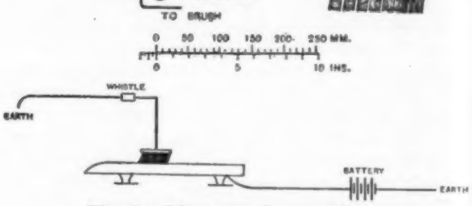
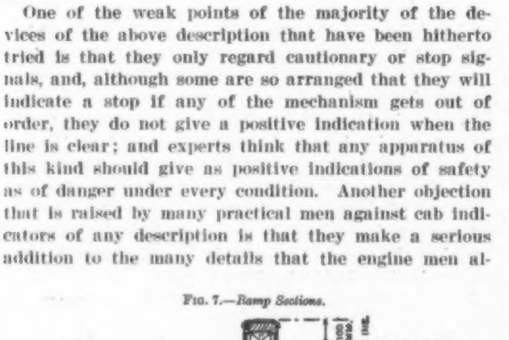


Fig. 6.—Diagram of connections.

these systems take a great variety of forms. In some an apparatus in the engine cab merely gives a visual repetition of the regular block signal, as displayed beside the track. In others there is both a visual and an audible signal given in the engine cab, and a recording apparatus is sometimes added. These are the systems that have been under trial in France for a number of years; while in England considerable experimenting has been done of late along the same lines, with, in some cases, the added element of devices that will stop the train if the engine-man neglects or overlooks an adverse signal.

One of the weak points of the majority of the devices of the above description that have been hitherto tried is that they only regard cautionary or stop signals, and, although some are so arranged that they will indicate a stop if any of the mechanism gets out of order, they do not give a positive indication when the line is clear; and experts think that any apparatus of this kind should give as positive indications of safety as of danger under every condition. Another objection that is raised by many practical men against cab indicators of any description is that they make a serious addition to the many details that the engine men already have to look out for,

FIG. 7.—*Ramp Sections.*



next some arrangement that will avoid the danger that may result from a sudden and complete application of the brakes. There is another point that demands careful consideration in this country, and that is weather conditions, for all kinds of cab signals and train stops include some sort of apparatus that is placed alongside the track, where it is liable to interference from snow or rain, and this is a serious matter, for it is just when the weather is unfavorable that all signals are most needed. The use of automatic train stops in the New York subway, where they have been remarkably successful, is often cited as showing the practicability of such devices; but the conditions of traffic there are greatly different from the requirements of the ordinary railroad, where train movements in both directions on the same track must be provided for, as well as switching and many other conditions that do not exist in the subway. In any case no system of engine cab signal or train stop can provide for accidents resulting from washouts, land slides, miscellaneous obstructions, failures in bridges, roadbed, track structure, or defects in rolling stock, as well as a long list of other unforeseen incidents.

A large number of American railroads are making experiments with auxiliary safety devices along the above lines, and it is to be hoped that their investigations will develop the additional safeguards that seem desirable in view of the high speeds and great weights of modern trains; and as throwing light on some phases of the situation the following extracts from notes on communications made at a meeting of the British Institution of Mechanical Engineers, held in Paris last summer, describing the various systems in use in France, will undoubtedly prove of interest.

NORTHERN RAILWAY.

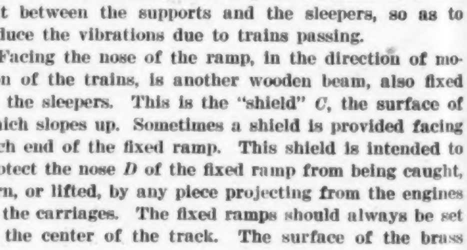
(*Chemin de fer du Nord.*)

A. Sartiaux, engineer-in-chief of the Traffic and Working Department, described the fixed ramp, the electro-automatic whistle on locomotives, and the electro-automatic indicator for trains passing distant

are used, placed end to end, in order to increase the duration of contact. The fixed ramp rests on the sleepers, on which it is held by wood screws; but care is taken in the first instance to pack cushions of tarred felt between the supports and the sleepers, so as to reduce the vibrations due to trains passing.

Facing the nose of the ramp, in the direction of motion of the trains, is another wooden beam, also fixed on the sleepers. This is the "shield" *C*, the surface of which slopes up. Sometimes a shield is provided facing each end of the fixed ramp. This shield is intended to protect the nose *D* of the fixed ramp from being caught, torn, or lifted, by any piece projecting from the engines or the carriages. The fixed ramps should always be set in the center of the track. The surface of the brass

FIG. 8.—*Diagram of the Electric Circuit.*



Diagrams of Electrical Connexions at "Danger" and "Safe" Positions.

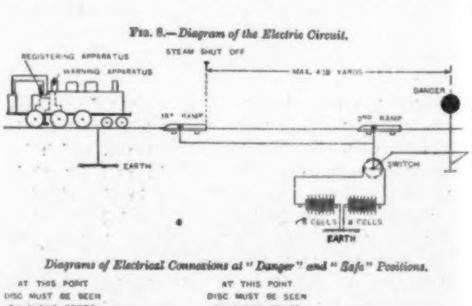


plate should be 10 centimeters (nearly 4 inches) above the level of the rails.

To place the fixed ramps in position, a special gage is used, Fig. 3. The maintenance of the contact surface of the fixed ramp in proper condition is effected by rubbing the brass cover plate with a cloth, and some very fine sand if it be very dirty; if soiled only, it can be cleaned with a damp cloth and thoroughly dried. Care must be taken that no dirt accumulates round fixed ramps, and in the winter they must be carefully freed of all snow. Again, when sleepers are changed there must be no accumulation of ballast round them.

The Electro-Automatic Whistle.—The whistle is an electro-automatic apparatus intended to warn drivers that they are reaching a distant signal set at "danger."

This apparatus, Fig. 4, which is installed on all locomotives, consists of a bronze bell-whistle *A*, and a lever *C* (carrying a plunger-valve *H*) which the tube *B* puts into communication with the boiler or with a compressed-air cylinder, the whole being bolted on to a cast-iron box fixed to the screen of the engine, in front of the driver. The lever *C* also carries a rod *F*, round which is a strong spring continually tending to pull the lever down and admit steam or compressed air to the whistle. *F* joins on, at its other extremity, to the arm *G* of a Hughes electromagnet *D*. If a current be sent through the coils in a certain direction, the magnet immediately ceases to attract its armature, the lever *C* comes down and the whistle *A* keeps going until the driver brings back the lever and the armature by pressing on the hand-lever *E*.

The Brush.—One of the wires of the electromagnet working the whistle connects with the body of the engine and goes to earth through the wheels and the rails; the other wire goes under the engine through a cable, perfectly insulated, and connects to the brush shown in Fig. 5. The brush consists of a series of small brooms of hard but elastic copper wire, soldered on to a metallic plate, which the cable aforementioned connects to the electro-automatic whistle. This apparatus is either adjusted at the engine shed to a maximum of sensitiveness in unclutching, a battery of three cells being used, or the engine is driven over a fixed ramp called a "testing" ramp, set at the exit from the shed, and which is directly fed by a battery of four cells as shown in Fig. 6.

The Switch and the Electric Circuit.—The signal vane is provided with a switch which is worked by a finger keyed on the signal post. This switch serves to control the position of the signal vane as well as to release the whistle. It is adjusted so as to work the bell registering at the station the position of the signal, and to release the whistle the moment the disk has turned 70 degrees from its normal position of "line clear." The brass plate having been connected with the positive pole of the battery placed near the disk, the negative pole is connected to the switch, which sends the current to earth when the disk is turned to danger, and disconnects it while the line is clear.

Fig. 1 explains the general installation and shows the electric circuit. The battery registering at the station the position of the signal vane has eight cells, the one connected to the fixed ramp has twelve cells. Both batteries are protected in a little cement inclosure built at the foot of the signal post. It is important that earthing be perfect.

Indicator for Trains Passing Distant Signals.—The indicator for trains passing distant signals is intended to give audible and visible warning to the station officials and the pointsman that a train is approaching. It consists of two fixed ramps *AA'*, Fig. 1, the first of which works the electro-automatic whistle as aforesaid, and the second the warning bell every time a train or an engine goes over it, this irrespective of the position of the signal vane.

The warning apparatus installed in the signal box consists of a loud warning bell provided with a little vane which becomes visible when the Hughes electromagnet, which is inside the apparatus, has been released by the brush going over the second fixed ramp. The appearing vane closes the circuit of a local battery on which is a loud trembling bell.

EASTERN RAILWAY.

F. Lancrenon, locomotive and rolling stock superintendent, sent a printed descriptive notice with detailed plans relating to the electrical warning- and recording-apparatus in use upon a certain number of locomotives on the Chemins de fer de l'Est (the Eastern Railway). He also sent a statement of several modifications made to the apparatus during the experimental period.

Extracts from the Printed Descriptive Notice.

The ramps used by this road are the same in dimensions, construction, and location as those used by the Nord, previously described, and are protected by the same kind of shield. *F*, Fig. 7, is a galvanized-iron cover closing the hollow cut into the beam to take the connection from the battery. The wire joins a copper bracket, which is riveted to the brass plate as shown.

Two fixed ramps are used, Fig. 8. The first is placed at the origin of a "field of vision" determined for the signal; the second at the foot of the signal itself. In this way, the position of the disk will be known, not only when the driver passed the signal, but also when he passed over the first ramp on entering the "field of vision."

Switch.—The switch at the signal-disk, which connects the two sets of batteries with the ramp, is in a cast-iron box, Figs. 9 and 10. The lever *B* is keyed on the shaft *A*, which is connected to the signal-disk. The shaft *A* carries several cams for different purposes. Two of these, *D* and *E*, are used in connection with ramps. Two springs, *F* and *G*, face cam *D*; two others, *H* and *K*, face cam *E*. When the disk is at danger,

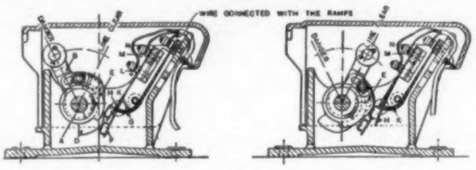


Fig. 9.—At danger, Fig. 10, at line clear. Switch at signal disk.

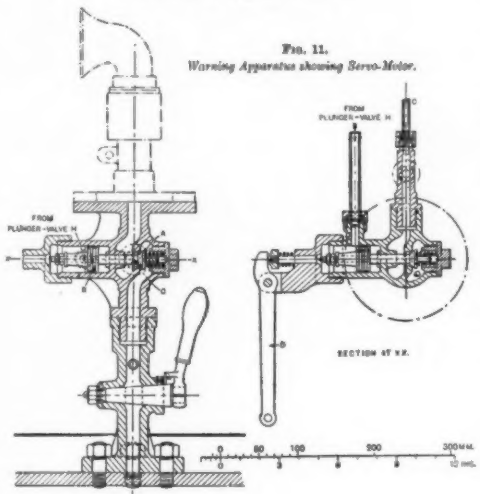


FIG. 11. *Warning Apparatus showing Servo-Motor.*

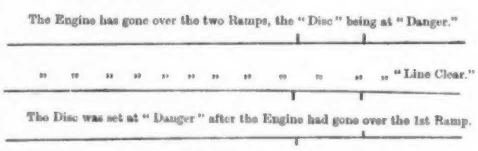


Fig. 12.

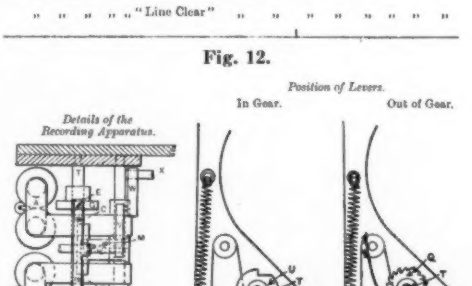


Fig. 13.—Speed indicator (Flaman).

Fig. 9, the lever *B* brings cam *D* to bear on the end of the spring *F*. This in its turn bearing on *G*, establishes the connection between the termini *L* and *N*, so that the positive pole of one of the batteries is connected with the ramp (*L* and *N* joining with the battery and the ramp). When the disk is at safe, Fig. 10, cam *E* bears on *H*, bringing it down to bear on *K*, thus connecting the termini *M* and *N*, so that the negative pole of the other battery connects with the ramp. The profile of the cams is such that contact is established when the disk has still to turn round 20 degrees before it is at "safe" or at "danger."

Warning Apparatus.—This is similar to the apparatus described for the Nord, but a horn is used instead of a bell-whistle, which means that more steam is required. In order to provide for this an additional device called a Servo-motor is introduced.

In Fig. 11 the rod of the valve *A* carries at its other end a piston *B*, which is acted upon by the steam which the plunger-valve *H* (Fig. 4, du Nord) has allowed to escape. As soon as the pressure of the steam on *B* becomes greater than that of the spring keeping the valve *A* back, the latter opens and the horn is fed directly from the boiler. In plan is shown a pipe *C*. This in certain cases is added to serve a second Servo-motor which brings the armature of the magnet back into position, so that the driver has nothing to do with the re-clutching and cannot stop the warning too quickly.

Five different devices have been tried for this:

(*a*) The first is a liquid speed-lag, working cataract way between two cylinders of different sizes, the larger one of which contains a piston which its rod connects with the lever of the electromagnet.

The escape through the small cylinder can be regulated so as to vary the speed of the piston.

(*b*) The second device disconnects the lever and the armature, so that the driver has no control of the apparatus until it is set to work once more by the brush going over another ramp.

(*c*) The third is purely automatic and consists of an auxiliary Servo-motor which draws the armature back.

(*d*) The fourth is a combination of the first and the third.

(*e*) The fifth is a device which the driver has to set by hand. Once he has set it the armature goes slowly back into position and the driver has no further control over it.

Again, the lever *D* is added so that the driver may work the horn himself, in case he wants to send special signals.

Recording Apparatus.—The record is taken on the tape of the speed indicator itself (Flamand system). A third stylo is fixed between the two recording the time and speed, and dots down the position of the signals passed. The apparatus consists of two "Hughes" electromagnets with their poles reversed, so that one is demagnetized by a positive current and the other by a negative current. The two magnets are in series and are connected at one end to the wire from the brush. The other end is connected to the engine and thence goes to earth. Under those conditions, supposing the disk is at "danger," one of the magnets will be demagnetized (the other holding its armature), and the stylo will make a mark on one side of the normal line. If the disk be at "safe," the other magnet will be demagnetized, and a mark will be recorded on the other side of the normal line. We have thus from the two ramps four combinations, Fig. 12. The leverage of the armatures is too weak to work the stylos so as to insure a distinct mark. The small leverage they give is used simply to work an auxiliary mechanism, which in its turn works the stylo. In Fig. 13 the armatures *A*, *B*, the arms of which turn freely round the shaft *L*, are acted upon by two springs, which tend to pull them away from the magnet, so that immediately one of the armatures is released it is pulled back. On the arms of the armatures are two pins, *C* and *D*. Either of these pins will, when one of the armatures is released, press against a lever *EF* which is pivoted at its center, and tilt it one way or the other until one of its ends bears on one of the toothed plates *G* or *H*. These plates, which carry three teeth each, are geared with the drum of the speed indicator through a bracket *M* keyed on the shaft *L*, and bearing on the arms of the armatures *A* and *B*. When one of the armature arms moves away from the magnet it presses the bracket back and turns the shaft *L*. A lever arm *O*, which is keyed to *L*, and which a spring keeps in position, then releases the ratchet *P* of the tooth-wheel *Q* and a small lever *R*, which then presses against an eccentric *S* keyed on the shaft of the drum of the indicator. The rotation of this eccentric *S* engages and releases the ratchet *P*, and *Q* turns round. As *Q* is keyed on the same shaft *T* as the toothed plates *G* and *H*, the latter turn round with it, thereby causing the lever *EF* to tilt up and down. This movement is carried to the stylo pen through the lever *V* which is keyed on the same shaft as *EF*. At one end this lever *V* carries a pin which presses against another lever *W* keyed on the shaft *X*. The movement is then communicated to the pen through a third lever keyed at the other end of the shaft *X*.

The mechanism stops thus: The arm *M* carries a catch, which bears on another toothed plate *U*, keyed on the shaft *T* immediately under *M*. As soon as this catch engages in the tooth of the plate *U*, the shaft *T* ceases to turn. The jerk is immediately taken up by the spring acting on the lever *O*, the ratchet *P* of the wheel *Q* unclutches, and the lever *R* is brought back, away from the eccentric *S*.

(*To be concluded.*)

Trouble has always been experienced on railroads by the destruction of the wooden sleepers at places where it was customary to clean the locomotive fires; and doubts have been expressed whether steel ties would not be subjected to excessive corrosion in the same situation. Experience on the Bessemer and Lake Erie Railroad, however, has demonstrated that such is not the case, as sleepers that have been in use from four to six years have not been seriously affected.

Geographic Aspects of the War—II*

How Topographical Conditions Affect Military Operations

By Prof. Douglas Wilson Johnson

Concluded from Scientific American Supplement No. 2073, Page 195, September 25, 1915

West of the San River the cuesta topography is less pronounced, but the plateau of southern Poland may represent its continuation, with a gentle slope toward the southeast and a poorly developed and very ragged escarpment facing northwest. If this is the case the upper Vistula would appear to flow along the depression formed by the intersection of the southeastward slope of the cuesta and the northward slope of the Carpathian piedmont plain, just as the San and Dniester Rivers flow in opposite directions along the depression of similar origin farther east. The surface of the south Poland cuesta or plateau is a forested upland having an average elevation of nearly a thousand feet over broad areas, and dissected by deep stream gorges which make the country difficult to traverse. It is complicated by a broad uplift in the Kielce district which brings older rocks to the surface and forms the heights of Lysa Gora, which rise far above the general level.

North of the Podolian cuesta and its westward continuation in south Poland stretches the monotonously level plain of central and northern Poland and East Prussia. Here the strata of recent geological age lie horizontal, and the only topographic features of importance are the river valleys cut into the plain and the glacial deposits laid down upon its surface. As the plain surface is usually but 300 or 400 feet above the sea, the rivers cannot cut deep trenches; but they have widened their valley floors, and meander extensively over the broad flood-plains deposited during periods of high water. Floods result from heavy rains in the Carpathians or from ice dams along the lower courses of the streams. The principal river is the Vistula, which from the junction of the Upper Vistula and San flows in a broad, shallow trench northwesterly through the Polish plain into Prussia, where it turns sharply northward to the Baltic. A majestic river of great volume, unfordable and seldom crossed by bridges, subject to terrible floods which may cover its entire valley bottom, it forms a serious obstacle to the enemy which would cross it; but a magnificent waterway, navigable for large vessels from the San to its mouth, for armies which are able to use it as a line of communication. Warsaw is located on a terrace 120 feet above the level of the stream, and therefore safe from damage by the floods.

The greater part of this plain has been glaciated, the ice sheet having reached nearly as far south as Lemberg. A mantle of glacial till covers much of the area, and has greatly disturbed the preglacial drainage. In the obstructed valleys, lakes and swamps are common, and vast areas of marsh characterize the undrained surface of the undulating till cover. In East Prussia a broad belt of terminal moraine forms the most important departure from the level plain topography. This morainic ridge, which reaches an altitude of 500 to 1,000 feet, trends southwest-northeast just north of the Polish border, and is noted for its intricate network of marshes and lakes, which culminate toward the east in the Mazurian lake district. Much of the country is wild, uncultivated areas of barren sand alternating with swamps and forest. Lyck, Allenstein, Tannenberg and Osterode lie within this belt.

The Russian Plan of Campaign. With the above-described elements of topography in mind, let us consider the general plan of the Russian campaign. One is tempted to measure the distance from the western border of Poland to Berlin and consider this as the distance Russian armies must move in order to threaten the German capital. This, however, is to ignore the absolute dependence of armies upon thoroughly safeguarded lines of communication. It would manifestly be impossible for a large Russian army to concentrate in western Poland and move on Berlin so long as an unbeaten German army occupied the morainic country of East Prussia, and a similar Austrian army existed in the rugged cuesta upland of Galicia; for as soon as the advance on Berlin was started, the lines of communication running from Russia through Poland to the army at the front would be in peril from a southward advance of the Germans debouching from the morainic hills, or a northward advance of the Austrians descending from the cuesta upland. If either advance succeeded in severing, even for a short period, those arteries which alone enable an army in the field to live, disaster to the Russians would speedily follow. It would be more accurate, therefore, to draw a line from the eastern point of the Prussian border southeastward to the eastern border of Galicia, and consider this as the line from which the Russian advance on Berlin must be measured. This, roughly, doubles the length of the advance.

Already in possession of the territory immediately in front of the center of this line, the Russians had to concern themselves with the hostile territory at the north and south. On the north the task was the most serious. Here were combined the most highly perfected military machine and the most difficult topography. The complicated maze of lakes separated by narrow necks of land easily fortified, marshes crossed by few good roads, and the main highway of travel. As the Russians fell back the Germans followed them into this difficult region. It is interesting to note that the Germans were now confronted with almost exactly the same topographic features which had opposed the westward movement of the Russians. Not only was there a region of hills, forests, lakes and swamps to be crossed, but beyond lay the valley of a large river, the Niemen, which, like the Vistula, runs from south to north across the path of advance. To correspond with the fortresses of Thorn and Danzig at two ends of the Vistula barrier stand the fortresses

Block diagram, showing topography of eastern theater of war.

Key to place names: *A*, Allenstein; *B*, Biala; *Br*, Bromberg; *D*, Debica; *Dr*, Drohobycz; *Du*, Dunajec; *G*, Grodek; *J*, Jozefow; *Le*, Leczyca; *Lo*, Lowicz; *P*, Plontek; *R*, Raba; *Rz*, Rzeszow; *S*, Sejuy; *Tn*, Tannenberg; *Tw*, Tarnow; *W*, Wislok; *Wa*, Wisloka.

therefore all but impassable for large bodies of invading troops, and forests through which invading armies must advance over occasional roads in long drawn-out columns peculiarly vulnerable to surprise attacks served to make a Russian invasion exceptionally difficult. In order to make an advance on Berlin from western Poland feasible, Russian armies must drive the Germans out of all that part of Prussia projecting east of the west Poland border. This would involve passing a very serious obstacle, the broad, shallow trench of the lower Vistula which cuts across the neck of the peninsula of eastern Prussia. The strength of this defensive line lies in the fact that the invaders would have to traverse the broad, flat floor of the valley under fire from artillery posted on the rest of the western valley wall, and would also have to cross an unfordable river of great breadth and volume; and in the further fact that each end of this line is guarded by a powerful fortress, Thorn at the south and Danzig at the north.

East Prussian Campaign. Into this morainic country of East Prussia the Russians launched a vigorous offensive in the first month of the war. Before the end of August, Russian armies had threaded their way through the forests, among the lakes and marshes, and over the rolling hills, always beating back the German defensive, until more than half the distance to the Vistula barrier had been traversed. Then two Russian army corps, caught in the mazes of the difficult region near Tannenberg by a successful German maneuver, were practically annihilated. The difficulties of negotiating the morainic defensive line in the face of the Prussian military machine had proved too great, and the Russian line fell back.

The morainic topography continues across the East Prussian border into Russia, where, in the region of Suwalki, one finds a country of forested, marshy fenland and lakes, perhaps even more difficult to cross than the region farther west, especially since roads and railroads are less numerous. From Suwalki eastward to Sejny a narrow causeway through the marshy forest is of Grodno and Kovno at the ends of the Niemen trench. This great topographic barrier is Russia's main protection against an invasion from Prussia. Behind it the retreating Russian armies took their stand about September 25th. Against it the German armies dashed themselves in a vain endeavor to pass over to the eastern side. After a vigorous artillery duel the German offensive waned, the Russians retook the offensive, and there began that pursuit of the German column back through the marshes and forests to the westward which is known as the Battle of Augustowo. Hampered by the broad marshes and few roads, the Germans lost heavily, particularly, it is reported, along the narrow Suwalki causeway. By the first week of October the German line had been pushed back into Prussian territory at the south and nearly to the Prussian border on the north. The topographic barriers of the Suwalki province had in turn proved too difficult for the German armies. By a slow and painful advance the Russians were able to reach the line of the Angerapp River and eastern side of the larger Mazurian lakes by November 15th, which excellent defensive line they held for three months against German attacks, until the sudden arrival of new German forces in February compelled another Russian retreat to the defensive line of the Niemen.

Galician Campaign. Turning now to the southern campaign, let us see what influence topography exerted upon the course of events in Galicia. In several respects topography here favored the Russian plans. No topographic barrier along the boundaries between Russia and Galicia prevents an easy invasion of the latter, whereas the formidable barrier of the Carpathians does separate Galicia from the rest of Austria-Hungary. Galicia is, therefore, a peripheral province, which is for topographic reasons peculiarly isolated from the rest of its country and therefore more easily subject to conquest by a neighboring power. During the invasion the deep gorge of the lower Dniester, and farther west the marshy flood-plain of the upper Dniester, would serve as admirable

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protections for the left flank of the invading army. Once the Austrian armies were pushed westward toward Cracow or southward over the Carpathians, the few passes over the latter could be held by small detachments of troops, and the left flank of the westward-moving Russian army would then have the effective protection of a mountain barrier; for while several roads and railways cross through the passes, they are so readily controlled that the strategic importance of the barrier is not greatly diminished. Austrian reinforcements would have to defile through the passes and along the few narrow mountain roads in greatly extended columns, a formation which would render them vulnerable to attack by inferior numbers. No sudden assault of serious magnitude upon an army flank, which is protected by a mountain barrier, is feasible.

With these favorable topographic elements was combined the further favorable fact that the Austrian armies were less formidable than the Prussian military machine. Political conditions in Austria-Hungary also dictated a vigorous Russian offensive in Galicia, since a nation composed of heterogeneous elements, some of them held in subjection against their will, can be more easily driven to seek peace after military reverses than can a nation which is better unified. Topographic, military and political considerations combined, therefore, to induce the Russian General Staff to subordinate the East Prussian campaign to far greater movements in Galicia.

There were, however, some formidable topographic obstacles to be overcome by the advancing Russian. The first of these of major importance was the Bug River, which receives the waters of numerous tributaries heading against the steep inface of the Podolian cuesta and flows northwestward through the Bug lowland to the Poland plain. Late in August, after a number of preliminary skirmishes, Russian armies invaded Galicia in force, driving back the Austrians to the valley of the Bug. The marshy flood-plains of this river, together with the meandering course and interlacing channels of the stream, afforded a good line of defense for the Austrians. The marshes were probably more formidable to the invader than was the channel of the river itself; for in negotiating them, troops must "defile" along the few good roads, crossing the wet lands in long, narrow columns which offer a good mark to the defenders, but which prevent the moving army from developing more than a fraction of its fighting power. On account of the water it is impossible to entrench in a marsh, so that the attacking force cannot profit by the temporary shelter of trenches during a slow advance. For these reasons marshes are usually considered one of the most serious obstacles which an army can encounter. It was not surprising, in view of the topography, to hear of fierce fighting along the line of the Bug River and to read in the despatches repeated references to the few towns, such as Sokal and Kamionka, marking the points where important roads cross the wet valley floor.

After defeating the Austrians along the Bug, the Russians in their westward advance soon reached the barrier presented by the steep face of the Podolian cuesta where it trends from southeast to northwest. The situation was much like that encountered by the Crown Prince's army in France when it attacked the steep escarpment of the east-facing cuesta near Verdun. In places the Podolian cuesta scarp rises several hundred feet above the Bug lowland, and is often quite precipitous, especially where resistant limestones composed of old coral reefs weather into nearly vertical cliffs. In other places the escarpment is lower, but steep, and may present nearly continuous wall for many miles at a stretch. Occasionally it slopes down more gradually to the plain as a forested hillside, while out in front are numerous erosion remnants in the form of mesas and buttes.

Whatever the local nature of the cuesta escarpment, it offers a serious obstacle to the troops which must cross the lowland toward it under fire of artillery posted on the crest, and then ascend the steep slope in face of the enemy's fire. We do not know just what was the disposition of the Austrian troops along this line; but we can hardly imagine that they failed to take advantage of the opportunities for defense offered by the cuesta topography. We do know that the great battles of Lemberg and Rawaruska were waged for the possession of the two strategic gateways through the cuesta, and that much of the fighting for Lemberg took place east of that city, probably along the face of the cuesta and the long foothill ridges which here extend many miles out into the lowland. That the Austrians did not hold this line longer was probably due in part to the fact that they had expected to fight the decisive battle farther north in Poland and had not kept sufficient troops in the southern district to cope with the unexpectedly large Russian army sent against them there; and probably also in considerable part to disorganization resulting from their defeat along the Bug.

An army advancing westward across the Bug lowland could not be wholly safe so long as its left flank was in danger of attack from Austrian forces operating in the rugged country on top of the cuesta to the south. It was therefore part of the Russian plan to sweep the Podolian plateau, as the cuesta upland is called, free of hostile troops. For this purpose the Russian line was continued southward in sufficient strength to make it possible to cross the deep north-south gorges of the parallel rivers in the face of any Austrian forces likely to contest their passage. These gorges present a succession of serious obstacles to the progress of an invader, and were not passed without fierce fighting at some of the principal crossing points. The gorge of the Dniester served to protect the left flank of the line, and the principal fighting occurred to the north of that barrier.

Immediately west of Lemberg lies the fortified town of Grodek, standing in one of the north-south parallel valleys, here occupied by a string of lakes connected with each other by rivers. Along this barrier the Austrians succeeded in checking the Russian advance for a short time. The next important physical barrier west of the Lemberg district is the marshy lowland of the San and upper Dniester Valleys. As already noted, this is one lowland formed by the intersection of the backslope of the Podolian cuesta and the Piedmont slope in front of the Carpathian barrier. The northeast flowing San and southeast flowing Dniester make an almost continuous river barrier along the lowest line of the lowland. Both rivers meander extensively on broad, marshy flood-plains on which are countless abandoned meander channels and oxbow lakes. Along the San the meanders are larger than those of the Dniester, and the oxbow lakes and crescent-shaped marshes are both larger and more numerous. Indeed, the lower San is characterized by a perfect network of these cutoff lakes and marshes, making passage across the flood-plain unusually difficult.

An obstacle like the marshy belt of the San-Dniester lowland, while a valuable line of defense for an army retreating in good order, becomes a serious menace to an army which has been badly beaten and is retreating in confusion before an energetic pursuer. Fleeing troops crowd in disorder toward the few passable roads leading over the marshy ground, and lose most of their fighting power as a consequence of the ensuing disorganization. After the battle of Lemberg the despatches repeatedly referred to the efforts of the Russians to drive the broken and defeated Austrian armies into the marshes to the west, where they could be overwhelmed with disaster. That these efforts were partially successful is indicated by the inability of the Austrians to hold the Russians in check along the San-Dniester line, and the evidently decreased fighting power of the Austrians during the immediately succeeding weeks. Przemysl, the great fortress which stands near the gap between the marshes of the San and those of the Dniester, was soon invested, and the Russians pressed on to seize the passes across the Carpathians southwest of the fortress, thus securing their left flank from danger of sudden attack in the future.

The conquest of the San-Dniester lowland by the Russians is of geographical interest from two other standpoints. Although a barrier to an invader, who would cross it, the lowland is one of the great routes of travel between central and southeastern Europe. The Carpathians on the southwest, and the vast marshes of the Pripet River across the Russian border to the northeast, restrict travel to the San-Dniester depression. Along its axis runs the main railroad connecting Bucharest and the Black Sea, via Czernowitz and Cracow, with Berlin and western Europe. The control of a natural highway continuing northwestward down the Oder to Berlin is of no small value to the armies which have Berlin as their ultimate objective. Of more immediate importance is the capture by the Russians of the oil fields on the southwest side of the lowland, especially near Drohobycz. From these fields came an appreciable part of the fuel used by the motor transport service of the German armies, and the loss of this source of supply must have been a serious blow to the Teutonic allies.

After passing the line of the San and Dniester, the Russians continued their westward advance toward Cracow. The topographic line of least resistance is here a subordinate lowland lying along the south side of the broader lowland already described, and just at the base of the Carpathian foothills. No one river flows through this minor depression, but parts of several rivers occupy it. Thus the lower Wislok follows it for twenty-five miles before joining the San, while large branches of the Wisloka flow easward and westward through it to join the trunk stream. The main railroad already described takes advantage of it in passing from Przemysl to Cracow. At its eastern end, just where the railroad enters the trench, stands the fortress of Jaroslaw; while at its western end, where it merges with the lowland immediately along the Upper Vistula, is the great ring fortress of Cracow.

The capture of Jaroslaw about the end of the third week in September gave the Russians full command of the entrance to this subordinate lowland or trench. About September 23rd they reached the strategic point Rzeszow, where the Wislok debouches into the trench; and a few days later Debica, where the Wisloka similarly flows from its mountain valley out upon the trench floor. By the end of the first week in October the invaders were in the vicinity of Tarnow, still farther west where the Biala River enters the trench to unite with the larger Dunajec. Thus the strategic points of which we heard most frequently mark the junction of transverse mountain valleys with the subordinate lowland parallel to the mountain base. During this advance troops were also moving westward through the mountains just to the south. Here they encountered the obstacles formed by the fairly open flat-floored valleys of the rivers mentioned above. Along all of these valleys, which lie across the line of advance, the Austrians offered resistance to the invader's progress. Occasionally these valleys expand into fairly broad intermont basins on whose level floors stand towns of more than ordinary size and military importance. Among those most frequently mentioned in the war despatches are Krosno in a basin on the Wislok; Gorlice, Zmigrod and Jaslo occupying the three corners of a triangular basin on the Wisloka; and New Sandek and Zakliczyn in separate basins on the Dunajec.

The subsequent retreat of the Russians from in front of Tarnow was not connected with any topographic obstacle in Galicia, nor indeed with any Austrian victory in this region. A German advance on Warsaw across the plain of Poland early in October made it necessary for the Russians to fall back at the south in order to keep their left wing in line with the retreating center. The retreat stopped at the admirable defensive line formed by the San River and its marshy flood-plain. Behind this barrier the Russians took up their position about October 11th; and whereas the broken Austrian armies retreating from the Lemberg region earlier in the campaign had been unable to profit by the natural defensive line of the San, the Russians now held it successfully against the Austrian attacks. A few Austrian troops succeeded in crossing the river at isolated points; but they were never able to effect a crossing in force, and the Russians maintained their position until the defeat of the Germans before Warsaw and their consequent retreat enabled the Russians to resume their westward advance in Galicia. During this second advance the subsidiary lowland from Jaroslaw to Cracow again exercised a controlling influence on the movements of the armies, while the transverse north-south valleys in the Carpathians provided a succession of defensive lines along which fierce battles were waged for a second time.

When the Germans began their second drive at Warsaw about the middle of November, the Russians had reached the environs of Cracow at the western end of the Galician lowland. As the Germans pushed eastward to the line of the Bzura, Rawka and Nida Rivers, the Russians in Galicia were again compelled to retreat. This time, however, they fell back a comparatively short distance, and took up a defensive position on the east bank of the lower Dunajec River soon after the middle of December. Aided by the natural protection which the river and its broad, flat valley afford, the Russians have now held this line for more than two months, notwithstanding vigorous efforts of Austro-German armies to dislodge them.

The Campaign in Poland. There remains for consideration the influence of topography upon the campaign in the Polish plain. We may note in the first place that the difficulty of transporting and supplying armies, which is such a marked characteristic of the campaigns in Poland, is itself in part a response to the physical conditions of the region. The long roads necessitated by the vast distances, while favored by the levelness of the surface, are of very inferior quality because the rocks underlying the plain do not supply a large amount of good road metal, and because the numerous marshes which the roads must traverse afforded exceedingly poor situations for road building. The construction of both roads and railroads is said to be discouraged by the excellence of the river transportation routes, which are navigable for large boats in Summer and are available for sledge traffic when frozen over in winter. Cross-country movements are limited, therefore, to a few long railroad lines and a comparatively small number of roads which become almost impassable in bad weather.

As we should expect in so level a country, rivers and marshes are the topographic features which have exercised the most evident effect upon the battle plans of the contending forces. During the first two months of the war the necessity of pushing the campaigns in East Prussia and Galicia, for reasons already indicated, led the Russians to pay little attention to operations in Poland. Raiding armies advanced and retreated along the few railroads for distances of a hundred miles without attracting serious attention, in view of the more important operations to the north and south. One striking exception to this statement is the important Austrian invasion of the Lublin district at the beginning of the war, during which advance and the subsequent retreat the barrier of the Vistula between Ivangorod and the Galician border was utilized as a protection for the Austrian left flank.

From the beginning of October, when the Germans commenced their first drive at Warsaw, the influence of

river valleys upon the distribution and movements of the troops becomes very noticeable. Threatened by the German advance, the Russians fell back to the best defensive line in all Poland, the valley of the Vistula. Once behind this barrier they could receive the shock of the German onslaught with greater confidence in the outcome, and could hold the enemy at bay until a proper concentration of forces would enable them to take the offensive. The Vistula in this part of its course is crossed by bridges at but two points, Warsaw and Ivangorod. Near the Galician border it has a breadth of nearly a quarter of a mile, and at Warsaw of fully one-third of a mile. It is everywhere too deep to ford. Along its valley bottom are extensive belts of marsh, while from the crest of the plain above artillery could effectively shell troops endeavoring to cross the river and marshes.

It was behind such a barrier as this that the Russians took up their position about October 10th. Only at Warsaw did they remain on the west bank, supported by the ring of fortresses which surround the Polish capital. From the Galician border the barrier is continued in the same straight line, as far as Przemysl, by the San River; and we have already seen that the Russians in Galicia fell back to this line in order to keep in touch with the armies farther north. For 250 miles or more an almost unbroken line of Russian troops from near Warsaw to Przemysl waited behind a great river barrier to receive the attack of the Austro-German forces. Never in history has so simple a topographic element been used for strategic purposes on so great a scale. Against this barrier some two million men hurled themselves in a determined effort to force a passage. Aside from the attempt to capture Warsaw, their greatest efforts appear to have been concentrated upon that part of the line near Josefow, where the Vistula is narrower than elsewhere, and the chances of effecting a crossing better. But all attempts to pierce the Russian line ended in failure, and the Russians launched a vigorous counter attack on the German left which soon bent that wing backward away from Warsaw until part of it was facing northward along the line of the Pilica River.

The continuation of this offensive compelled the Austro-German forces to retreat along the entire line. It was generally anticipated that the retreating armies would make their first stand at the Warta River, and attempt to utilize that topographic feature as effectively as the Russians had utilized the Vistula-San Valley, especially since it was reported that active work in fortifying this line had been going on for some weeks. But whether because the pursuit by the Russians was pushed too vigorously, or because the Teutonic allies preferred a line nearer their strategic railways just inside the Posen border, the Warta valley was crossed before the Russian pursuit was brought to a standstill, about the middle of November.

Immediately, there began the second German drive at Warsaw. During the German advance and Russian retreat a portion of the Warta valley was held for a time by the Russians to cover the retirement of their main force; but a more striking influence of topography on army movements may be seen by examining the battle line of November 17th–19th. At this time the line of contact between the two armies, after running northward through western Poland to Leczyca, turned due east toward Warsaw for 30 miles to Lowicz, whence it bent toward the north once more. The reason for this peculiar alignment is not far to seek. The Bzura River flows eastward from Leczyca to Lowicz in a shallow trench cut in the plain, and then turns gradually northward to the Vistula. Westward from Leczyca the trench continues, but is there occupied by a westward flowing branch of the Warta. For a distance of 60 miles the floor of this trench is practically one continuous belt of marsh, with one important causeway crossing it near Piontek, half-way between Leczyca and Lowicz; and another at Leczyca. Confronted by superior German forces advancing eastward from the Posen border, the Russians decided to fall back toward the south and take up a defensive position on the southern side of the marsh belt until reinforcements could arrive. In this position they could also protect the city of Lodz, which lay a few miles farther south. For a short time they did succeed in holding the marshy barrier against the attacks of the enemy; but apparently the western part of the German line, already south of the marsh, forced the evacuation of Leczyca, while determined frontal attacks enabled the Germans to cross the causeway at Piontek. There followed that most remarkable confusion of the two lines, when the Germans who had broken through at Piontek nearly surrounded a portion of the Russian army at Lodz, and were in turn themselves surrounded by the Russians. When the lines were finally straightened out the Russians were gradually forced back until they took up a new defensive line running from north to south along the eastern banks of the lower Bzura, the Rawka, the Nida, and the lower Dunajec rivers. Thus by the end of the third week in December the Russians were again lined up along a north-south barrier consisting of parts of several different rivers. This line they still held at the end of February.

During the second German advance toward Warsaw, which was stopped by the Russian defensive along the line just indicated, the Germans made excellent use of the lower Vistula, from the mouth of the Bzura to Thorn, as a protection for their left flank. Ever since the middle of December the Germans south of the lower Vistula have been far to the eastward of Russian troops posted on the northern bank. At times large Russian forces have advanced along the north bank well toward Thorn, and more than fifty miles west of the German front along the Bzura. This was possible because the great river, here bridged only at Plock and Wloclawek, made it almost impossible for the Russians to come to the south side and attack the German flank. Small German forces at critical points on the south bank of such a barrier could insure the safety of lines of communication supplying armies along the Bzura front. On the other hand, the Germans have been largely denied the use of the Vistula itself as a line of communication, as attempts to bring supplies by boat from Thorn have been more than once thwarted by the activity of the Russian artillery posted on the northern bank of the river. In this connection it may be noted that the Germans in East Prussia have often operated far in advance of the rest of their line in Poland, because the east-west belt of difficult morainic country serves as a protection against sudden flank attacks from the south.

The important strategic rôle played by the rivers and marshes of the Polish plain could be traced much further if space permitted. Enough has been shown, however, to justify the conclusion that these two elements of Polish topography have been much utilized by both combatants. In conclusion, it may be pointed out that after the failure of the dash to Paris the Germans probably hoped to take possession of the line of the Niemen-Narew-Vistula-San before the beginning of winter. They could then entrench themselves along this continuous marsh and river barrier, holding the Russians at bay with as small a force as practicable and freeing the largest possible number of troops for a renewed offensive in the west. Such a line could have been readily defended because of its physical character, and would have had the added advantage of lying mainly on Russian soil and including within its limits the captured Polish capital. The project failed because the Russians themselves made effective use of this same line of barriers in their operations against the Germans, and were ultimately able to take and hold positions along another line farther west.

Economizing Zinc

In the engineering profession, it is a well-known fact that the best rolled zinc has the power of partially allaying and transferring to itself the harmful corrosive action that occurs in steam boilers and condensers, and for this purpose huge quantities of zinc are used and consumed, which can never be recovered. Mr. H. de B. Parsons, B.Sc., M.E., a well-known authority on boiler construction, in his book, "Steam Boilers," gives the following rule: "That one square foot of surface of pure zinc be used for every fifty square feet of heating surface for the protection of a boiler, and that this zinc be renewed at frequent intervals."

On inquiry, it has been ascertained that Mr. H. de B. Parsons's basis has been adopted among engineers universally both in his Majesty's navy and in the mercantile marine. This being the case, if we take for example the amount of zinc being used annually in the boilers of one of the largest Atlantic liners, which has a heating surface of 158,350 square feet in twenty-five boilers, and if the plates of zinc were as advocated—namely, 6 feet by 6 feet by 1 foot—and had to be renewed, as usual, every three months, this vessel alone would consume 14,400 pieces of zinc per annum, or a total weight of this metal of 129,600 pounds, or 57 tons 17 hundredweight 16 pounds, which, taking the price per ton as $725, is worth over $35,500. If this amount of zinc had not been used for this purpose, but had been mixed with copper to form brass, 17,280,000 service rifle cartridges could have been manufactured. And these figures relate to only one ship for one year!

There is now no longer any necessity for this waste to continue. The beneficial result derived from the use of zinc in boilers is purely electrolytic, the boiler being made into a huge primary battery. This being so, it would appear to be obvious that this method could be discarded and better results obtained by using the secondary source of electrical energy that is always present on board ocean-going liners—i. e., the ship's power and lighting dynamo. This method is already in practice, and giving excellent results, and where in use all zinc has been discarded. This being the case, it behooves both the Admiralty and the mercantile marine, and, in fact, all steam users, to embrace the more scientific principle, and so release many thousand tons of zinc, that, when mixed with copper to form brass, would make billions of rounds of cartridge cases and would have the advantage of helping our government and putting hundreds of thousands of pounds in the steamship owners' pockets.—*The London Daily Telegraph.*

Two students of the University of Washington have undertaken the construction of what is said to be the largest testing transformer on the Pacific Coast, as a thesis for a degree in engineering. They are Leo Dashley and Joan Dodds, both Seattle men. The transformer, which will be ready for use in the spring, will be surpassed only by those in the testing laboratories of some of the big electrical companies. The apparatus is to be set up in the engineering building for research work and the testing of insulating materials. It will be 7 feet high, 4 feet wide, and 2 feet thick, will contain 300 pounds of wire, and will step up the voltage from 220 to 220,000.

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